DOCUMENT RESUME

ED 053 540 EM 009 115

| | |
|---|---|
| AUTHOR | Ohlman, Herbert |
| TITLE | Communication Media and Educational Technology: An Overview and Assessment with Reference to Communication Satellites. |
| INSTITUTION | Washington Univ., St. Louis, Mo. |
| SPONS AGENCY | National Aeronautics and Space Administration, Washington, D.C. |
| REPORT NO | R-T-71-1 |
| PUB DATE | May 71 |
| NOTE | 252p.; Program on Application of Communications Satellites to Educational Development; Thesis submitted to the Sever Institute of Washington University |
| EDRS PRICE | EDRS Price MF-$0.65 HC Not Available from EDRS. |
| DESCRIPTORS | Airborne Television, *Communication Satellites, Computer Assisted Instruction, Computer Output Microfilm, Dial Access Information Systems, Display Systems, *Educational Development, *Educational Technology, Electronic Equipment, Facsimile Communication Systems, *Information Dissemination, Input Output Devices, Instructional Materials, Instructional Systems, *Instructional Television, Library Circulation, Microforms, Telecommunication, Telephone Communication Systems |
| IDENTIFIERS | Education Satellite, EDUSAT, Midwest Program on Airborne Television Instruction, MPATI |

ABSTRACT

In this survey and analysis of the present state and future trends of communication media and educational technology, particular emphasis is placed on the potential uses of communication satellites and the substitution of electronic transmission for physical distribution of educational materials. The author analyzes in detail the characteristics and applications of technology which might be utilized in such an educational communication satellite system, giving detailed descriptions of still-picture television (in which the full-motion capability of television is given up in favor of bandwidth conservation and greater program diversity), of computer-assisted instruction (CAI), computer-controlled instructional television CAI systems, and interactive graphic display systems. In discussing the complex trade-offs between communications and transportation in the delivery of educational materials, he examines the potential of such technologies as facsimile transmission and computer output microfilm for delivering printed materials, and he suggests such wired-communication devices as Picturephone, cable television, cassette, and disc program storage systems for non-print media. He outlines in qualitative terms how such media and technologies might be utilized in a satellite-based multipurpose educational service. [The author of this survey requests that this presentation not be offered to the users in hard copy.] (JY)

ED053540

PROGRAM ON APPLICATION OF COMMUNICATIONS SATELLITES
TO EDUCATIONAL DEVELOPMENT

WASHINGTON UNIVERSITY

Report No. T-71/1

May, 1971

# COMMUNICATION MEDIA AND EDUCATIONAL TECHNOLOGY: AN OVERVIEW AND ASSESSMENT WITH REFERENCE TO COMMUNICATIONS SATELLITES

Herbert Ohlman

EM009115



WASHINGTON UNIVERSITY / SAINT LOUIS / MISSOURI 63130

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# COMMUNICATION MEDIA

# AND

# EDUCATIONAL TECHNOLOGY:

# AN OVERVIEW AND ASSESSMENT WITH REFERENCE TO COMMUNICATION SATELLITES

BY

Herbert Ohlman

Prepared under the direction of Professor R. P. Morgan

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A thesis presented to the Sever Institute of
Washington University in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE

June, 1971

Saint Louis, Missouri

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ABSTRACT

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# COMMUNICATION MEDIA AND EDUCATIONAL TECHNOLOGY: AN OVERVIEW AND ASSESSMENT WITH REFERENCE TO COMMUNICATION SATELLITES

by Herbert Ohlman

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ADVISOR: Professor R. P. Morgan

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June, 1971

Saint Louis, Missouri 63130

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This paper presents a survey and analysis of the present state and future trends of communication media and educational technology. Particular emphasis is placed upon the potential uses of communication satellites to help meet the future needs of education in the United States, and upon the substitution of electronic transmission for physical distribution of educational materials.

A multipurpose educational satellite service is proposed, based on supplementing conventional instructional television programs with the electronic transmission of a variety of materials, using such television-compatible media as still-picture television, computer-assisted instruction, and facsimile.

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# COMMUNICATION MEDIA AND EDUCATIONAL TECHNOLOGY: AN OVERVIEW AND ASSESSMENT WITH REFERENCE TO COMMUNICATION SATELLITES

## 1. INTRODUCTION AND BACKGROUND

### 1.1 INTRODUCTION

The International Development Technology Program at Washington University has been engaged in an interdisciplinary program on the "Application of Communication Satellites to Educational Development" under a NASA grant (1).* The program has the following broad objectives:

1. To examine the potential applications of communication satellites to the improvement of education, primarily in the United States.
2. To generate basic knowledge to aid in making rational decisions concerning the application of communication satellites to education in the near future.
3. To devise systems and to suggest strategies for the improvement of education utilizing communications satellites, and to provide for the evaluation of systems effectiveness.
4. To provide for the education of individuals knowledgeable about satellite communications policy, in an interdisciplinary manner,

* The numbers in parentheses in the text indicate references in the Bibliography.

and particularly as related to the important social application of education.

Vital elements of any educational communication satellite system are the media which are to be transmitted, and the determination of the best interfacing between each medium and the learner who is utilizing it. Several previous studies of a television broadcast satellite have been made for NASA by such firms as General Electric (2)*, TRW Systems (3), and General Dynamics/Convair (4). AID has funded Stanford Research Institute to study satellite-based TV for developing countries (5), and several university-based studies have been done, such as at Stanford (ASCEND) (6), West Virginia University (STRIDE) (7), Old Dominion College (EDUSAT) (8), and the Indian Institute of Technology at Kanpur (ACME) (9). All these studies have placed major emphasis upon satellite technological requirements, but relatively little attention has been given to ground facilities and their utilization for educational purposes.

Also, there has been a proliferation of new hardware for education, particularly during the last decade. This field,which has come to be called educational or instructional technology, is as yet not well documented. A great deal of the information is available only in manufacturers literature and unpublished reports. This information requires careful evaluation, particularly as educational technology is considered in the context of large-scale communication systems for education.

The over-all purpose of this report is to summarize and evaluate the development of communications media and educational technology in the recent past, project it into the near future, and relate this field

to the requirements of an educational satellite system. Specifically, the study reported herein has the following objectives:

1. To determine the characteristics and applications of communications media which might be utilized in an educational communication satellite system, with particular emphasis upon what Bretz defines as audio-still-visual media (10)
2. To evaluate the role which new instructional technology might play in conjunction with an educational satellite system.
3. To examine the impact of technology based upon the physical distribution of materials, for example, tape cassettes, upon the need for electronic distribution of the information contained in such materials.
4. To suggest ways in which an educational satellite system utilizing instructional media and technology might evolve.

In essence, this study is intended to provide essential background material on communications media and instructional technology to the designer of educational communication satellite systems. It extends and updates the communications media study of Bretz (10), giving particular attention to media compatibility with satellite transmission requirements. Although this study suggests how educational media and technology may be utilized in conjunction with an educational satellite system, it is not intended to be a systems design study in the quantitative sense. Every attempt has been made to provide accurate market prices whenever possible. However, it should be kept in mind that costs change, and in particular cost estimates of new products and systems are subject to wide fluctuations until they actually reach the market.

## 1.2 EDUCATIONAL TECHNOLOGY

Education today is among the largest public expenditure segments of the American economy. During the 1967-68 school year, $57.477 billion was expended on education, or 7.2% of calendar 1967 gross national product of $793.544 billion. Two years later, the educational share grew to 7.5% of an estimated $932.1 billion, or $69.5 billion (11). It appears likely that education may be nearing saturation in its relative share of the national economy.

Current attempts to increase taxes for education have been meeting stiff opposition throughout the country. This is particularly evident in public elementary and secondary education, whose major source of revenue for operating expenses has traditionally come from local property taxes. At present, 52.7% of school revenues come from local sources, 39.9% from state support, and 7.4% from the Federal government (12). The state share has remained relatively the same during the past decade, but the local share has diminished, while an increasing proportion has come from the Federal government. This trend may very well increase, under the impact of revenue sharing now being proposed by President Nixon. If these proposals become law, the apparent proportion attributable to state support will increase. Another sign of saturation in educational expenditures is that 70% of recent bond issues for capital improvements of educational plant have been rejected by the voters at the local level (13).

As public scrutiny of educational expenditures increases, so does the desire to see what the public is getting for its money. This has led to the idea that schools should be held accountable (14) for the revenue they receive, perhaps in terms of measurable gains in such fundamental

learning areas as reading and arithmetic. Another approach is to provide educational alternatives to the classroom, which would be allowed to compete for support with the schools (15, 16). There is considerable evidence that universal public education in its traditional guise cannot meet all the needs of the diversity of students it must accommodate. Perhaps 25% of all students, as high as 60% in some communities, are functional illiterates, and less than 30% of entering first-graders finish high school (13).

Another severe problem is the labor-intensive character of elementary and secondary education. Two-thirds of current expenditures goes to pay for instructional staff, but only 3.3% is spent for textbooks, materials, and equipment, not including audiovisual equipment or teaching systems (17). At least part of the latter two categories can be estimated from an analysis of the audiovisual market, which showed all school expenditures for such equipment and materials totalling $570 million during 1968 (18). If half of this can be attributed to elementary and secondary use, it would only add another 0.5%.

Also, research and development funds for education have lagged behind most other economic segments. For example, 2.8% of the 1969 GNP, or $26.25 billion (11), was devoted to all types of research and development, while only $192 million, or 0.31% of a total educational expenditure of $54.6 billion was devoted to educational research and development in 1968 (19).

Even so, Federal educational research and development support has increased tenfold from 1960 to 1968, and reached $171 million in fiscal 1968 (19). Correspondingly, there was an increase in the involvement of industrial firms in education, influenced by increased Federal support,

and by the attraction of a seemingly huge and growing market: the "knowledge industry". However, many of the newer entrants to the knowledge industry, including such corporate giants as IBM, RCA, General Electric, and Xerox, misjudged the nature of the education market, and its capacity to absorb rapid change. The acquisition by these firms of textbook houses and other software-oriented businesses, and their disappointing performance in the marketplace have been related elsewhere (20-23).

Within the knowledge industry, particular attention has been given to technology, which in other areas has provided great cost-benefit advantages. This field, called educational or instructional technology, has been based to a considerable degree upon the older field of audio-visual aids, with the addition of such newer developments as programmed instruction and computer and communication technology.

During the sixties, the Federal government gave its enthusiastic support to these developments. A summing up of Government involvement in educational technology and recommendations for its future participation on a much larger scale are given in a recent report of the Commission on Instructional Technology to the President and Congress entitled "To Improve Learning." The opening paragraph provides two contrasting definitions of the field:

> "Instructional technology can be defined in two ways. In its more familiar sense, it means the media born of the communications revolution which can be used for instructional purposes alongside the teacher, textbook, and blackboard. . . television, films, overhead projectors, computers. . .these media have entered education independently and still operate more in isolation than in combination.
>
> "The second and less familiar definition of instructional technology goes beyond any particular medium or device. . .it is a systematic way of designing, carrying out, and evaluating the total process of learning and teaching in terms of specific

> objectives, based on research in human learning and communication, and employing a combination of human and non-human resources to bring about more effective instruction." (24)

The Commission generally followed the first definition, leaving the acceptance of the broader interpretation to the future. This is indicative of the difficulty of making widespread changes in the field of education.

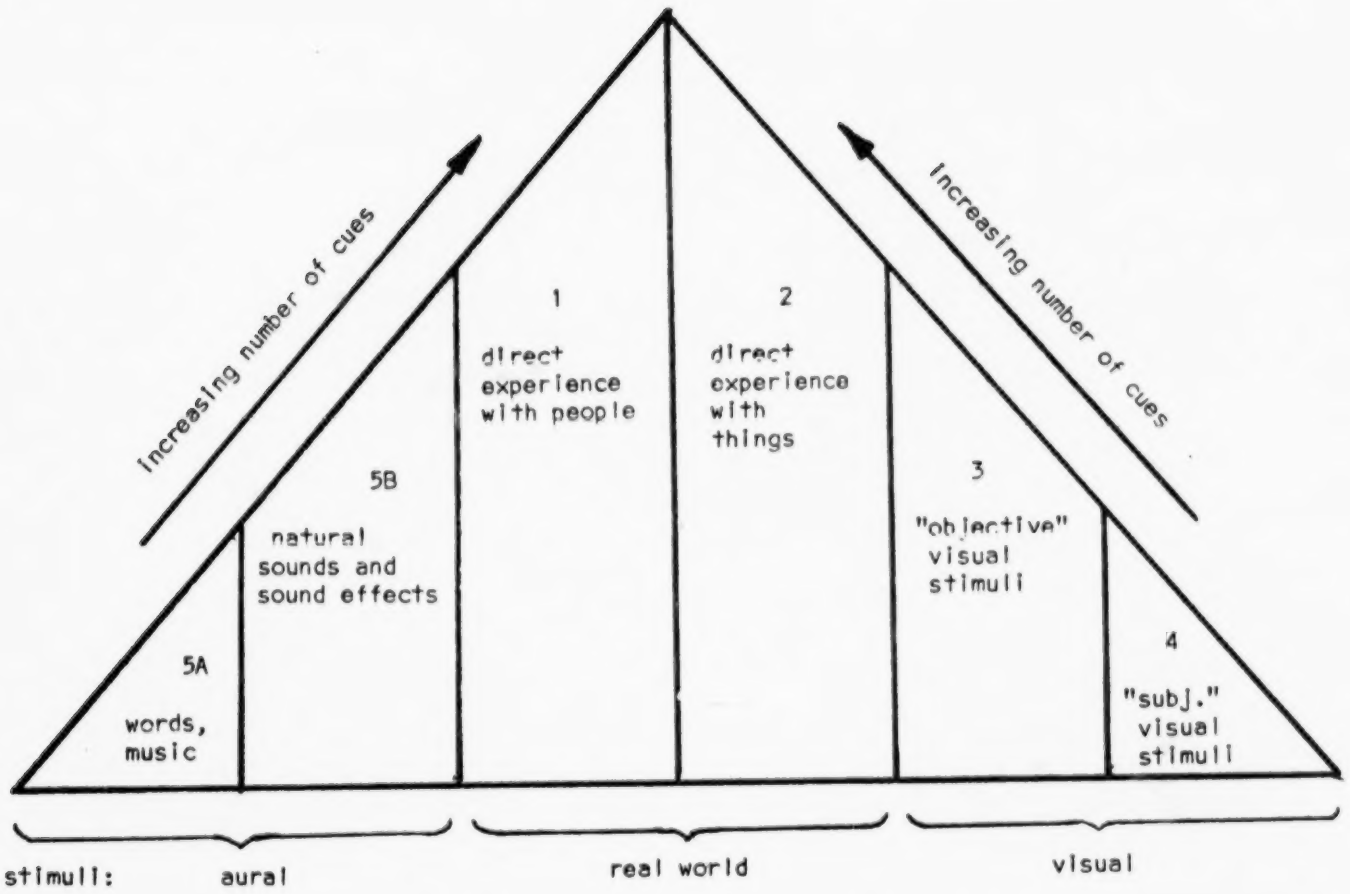
However, instructional technology as represented by the first definition has not had the impact upon educational practice hoped for. A great many educators have given the new media a try, but have been rebuffed by the fragmented market, and a lack of long-term support from its members. As Richard Hooper, a staff consultant to the Commission, has said:

> "Educational technology will remain on the periphery without resources unless educational administrators--and the civilian administrators above them, for example school boards--give it top-level commitment. The piecemeal approach must be discarded." (25)

## 1.3 COMMUNICATION MEDIA

To utilize the wide variety of media available effectively, an understanding of the capabilities and limitations of each type is essential. Several classifications or taxonomies have been devised for educational media. Dale used a "cone of experience" to classify key audiovisual materials on a "continuum from the concrete to the abstract" (26). Edling used a similar concept, in the form of a triangle, to depict "stimulus dimensions", which are graded according to the number of cues they provide (Figure 1) (27).

Flory and Allen surveyed audiovisual devices for use in education for a U. S. Office of Education/Society of Motion Picture and Television




(verbal behavior important)

1. Direct experience with people: demonstration, discussion, puppets, tableaux, pantomine, play, sociodrama, authentic situations. (overt behavior important)

2. Direct experience with things: mockup, model, specimen, object itself.

3. "Objective" visual stimuli: cartoon, color cartoon, animated color cartoon, sketch, photograph of painting, painting, 2-D still picture, 2-D color still picture, 3-D still picture, 3-D color still picture, motion picture, 3-D motion picture, 3-D color motion picture.

4. "Subjective" visual stimuli: abbreviations and symbols, words, numbers, charts and graphs, maps, diagrams, symbolic cartoons.

5. Audio stimuli:
   A. "Subjective": words, musical instruments.
   B. Recorded sound effects, real sound effects, recorded natural sounds, hi-fidelity natural sounds, stereo hi-fidelity natural sounds.

Note: Within each of these categories, the examples are arranged from the most-structured instructional situations to the least-structured.

Figure 1: Edling's Categorization of Stimulus Dimensions
(from Reference 27)

Engineers Conference (28,29). They related four previous classifications, by Porter (30), by Carpenter, by the Association for Supervision and Curriculum Development (ASCD) (31), and by Spaulding (Table 1). Each of these classifications emphasizes different aspects of the audiovisual field: equipment, function, media characteristics, and conditions of use, respectively. The USOE-SMPTE Conference participants could not come to any agreement on the best classification, so Flory and Allen limited themselves to an unstructured list of 22 devices for audiovisual instruction (28).

Saettler published the only comprehensive history of instructional technology, but did not present a formal classification (32).

Recently, Bretz devised a new taxonomy, giving particular attention to telecommunications aspects of media (10). Seven major classes were employed, and examples of generic types of media listed in two columns, headed "telecommunication" and "recording". Also, the capabilities of each medium type in relation to five different stimulus types was indicated (Figure 2).

Bretz has coined or adopted several terms for this taxonomy, such as "telewriting", which he defines as:

> "An instructional media system which transmits sound and writing as it is being written. The principle is basically that of the TelAutograph: The vertical and horizontal components of movement of the sending stylus are transferred to electrical impulses which are then transmitted on different channels to a receiving stylus which moves in accordance with the signals it receives, and reproduces, simultaneously, the original writing. This may then be projected on a screen for group viewing." (10)

The term has appeared in dictionaries, but with widely varying meanings. For example, Webster's Third New International Dictionary defines telewriting as a British term for what Americans call telautography (33),

Table 1: Media Taxonomies*

| By hardware (D. Porter) | By function (C. R. Carpenter) | By media characteristics (ASCD) | By conditions of use (S. Spaulding) |
|---|---|---|---|
| Stimulus devices:<br>visual<br>auditory<br>audiovisual<br>tactile<br><br>Response devices:<br>data manipulators (direct)<br>data gatherers (indirect)<br><br>S-R devices:<br>simulators<br>immediate reinforcers<br>pacers | communication cycle:<br>manipulation, organization, & recording of information<br>origination of information<br>distribution of information<br>presentation of information<br>implementation of learning responses | sensory appeals<br>symbol types<br>degrees of permanency<br>physical availability<br>degree of availability to student audience characteristics<br>economic availability<br>psychological potential | in-school:<br>large-group<br>individual & small-group<br><br>home instruction |

*Summary of information from J. Flory & W. H. Allen (28)

| TELECOMMUNICATION MEDIA | Sound | Picture | Line Graphic | Print | Motion | RECORDING MEDIA |
|---|---|---|---|---|---|---|
| | | CLASS I: AUDIO-MOTION-VISUAL MEDIA | | | | |
| | X | X | X | X | X | Sound film |
| Television | X | X | X | X | X | Video tape |
| | X | X | X | X | X | Film TV recording |
| Picturephone | X | X | X | X | X | |
| | | CLASS II: AUDIO-STILL-VISUAL MEDIA | | | | |
| Slow-scan TV<br>Time-shared TV | X | X | X | X | | Recorded still TV |
| | X | X | X | X | | Sound filmstrip |
| | X | X | X | X | | Sound slide-set |
| | X | X | X | X | | Sound-on-slide |
| | X | X | X | X | | Sound page |
| | X | X | X | X | | Talking book |
| | | CLASS III: AUDIO-SEMIVISUAL MEDIA | | | | |
| Telewriting | X | | X | X | X | Recorded telewriting |
| | | CLASS IV: MOTION-VISUAL MEDIA | | | | |
| | | X | X | X | X | Silent film |
| | | CLASS V: STILL-VISUAL MEDIA | | | | |
| Facsimile | | X | X | X | | Printed page |
| | | X | X | X | | Filmstrip |
| | | X | X | X | | Picture set |
| | | X | X | X | | Microform |
| | | X | X | X | | Video file |
| | | CLASS VI: AUDIO MEDIA | | | | |
| Telephone<br>Radio | X | | | | | Audio disc<br>Audio tape |
| | | CLASS VII: TYPE MEDIA | | | | |
| Teletype | | | | X | | Punched paper tape |

Figure 2: Bretz' Two-Dimensional Taxonomy of Communication Media
(from Reference 10)

while the British "Chambers Technical Dictionary" directly contradicts this in its definition of telewriter:

> "an obsolete system of transmitting messages whereby the excursions of a pen were transmitted by direct currents over a line; these operated a similar mechanism, which wrote out the message." (34)

In this country, the term telautograph seems to be preferred, but is found most frequently as the trade name TelAutograph. "Electronics and Nucleonics Dictionary" defines it as:

> "A writing telegraph instrument in which manual movement of a pen at the transmitting position varies the current in two circuits in such a way as to cause corresponding movements of a pen at the remote receiving instrument. Ordinary handwriting can thus be transmitted over wires." (35)

To add to the confusion, none of these definitions mentions sound transmission. In this report, the term will be used, but will not be as restricted in definition as Bretz has made it. Thus, telewriting will be used to describe any system--wire or wireless--of remote freehand writing or drawing, with or without the coordinated transmission of voice.

"Still-picture television" appears to be a term coined by Bretz for his Class II: audio-still-visual media. In Chapter 2, particular attention will be given to still-picture television, which may be considered as a system for transmitting still pictures of many different kinds, with coordinated sound.

A new taxonomy has been devised in connection with this study to depict the relationships between various media and their stimulus characteristics in detail, giving visual and aural stimuli equal weight (Figure 3). Porter (30) also included tactile stimuli, but they are not indicated on this chart except indirectly in the response category. The

| MEDIUM \ SENSORY CAPABILITIES | | | | | VISUAL CAPAB | |
|---|---|---|---|---|---|---|
| | signals | symbols | | graphs, charts, drawings (vector capab.) | black & white pictures | |
| | | numerals, operators | alphanumerics, special symbols | | low fidelity (limited grey scale) | high fidelity (full grey scale) |
| VISUAL MEDIA: handwriting, line drawing | | | | | | |
| VISUAL MEDIA: sketching, painting | | | | | | |
| VISUAL MEDIA: printing, graphic arts | | | | | half-tones | |
| VISUAL MEDIA: projected: slides, filmstrips, overhead transparencies | | | | | | |
| VISUAL MEDIA: projected: microimaging | | | | | | |
| VISUAL MEDIA: X'mtd: facsimile | | | | | | Wirephoto |
| AURAL MEDIA: audio | | | | | | |
| AURAL MEDIA: transmitted: telephone | | | | | | |
| AURAL MEDIA: transmitted: radio | | | | | | |
| AUDIOVISUAL MEDIA: projected: sound slides, filmstrips | | | | | | |
| AUDIOVISUAL MEDIA: projected: motion pictures | | | | | | |
| AUDIOVISUAL MEDIA: projected: telewriting | | | | | | |
| AUDIOVISUAL MEDIA: still-picture TV | | | | | | |
| AUDIOVISUAL MEDIA: transmitted: Picturephone | | | | | | |
| AUDIOVISUAL MEDIA: transmitted: television | | | | | | |
| INTERACTIVE MEDIA: input devices | | buttons | dials | keyboards | Graphacon | |
| INTERACTIVE MEDIA: computer-controlled display devices | | switches lights | | readouts | cathode-ray tube (CRT) | projected images |
| | | | | | COM | x-y plotter |

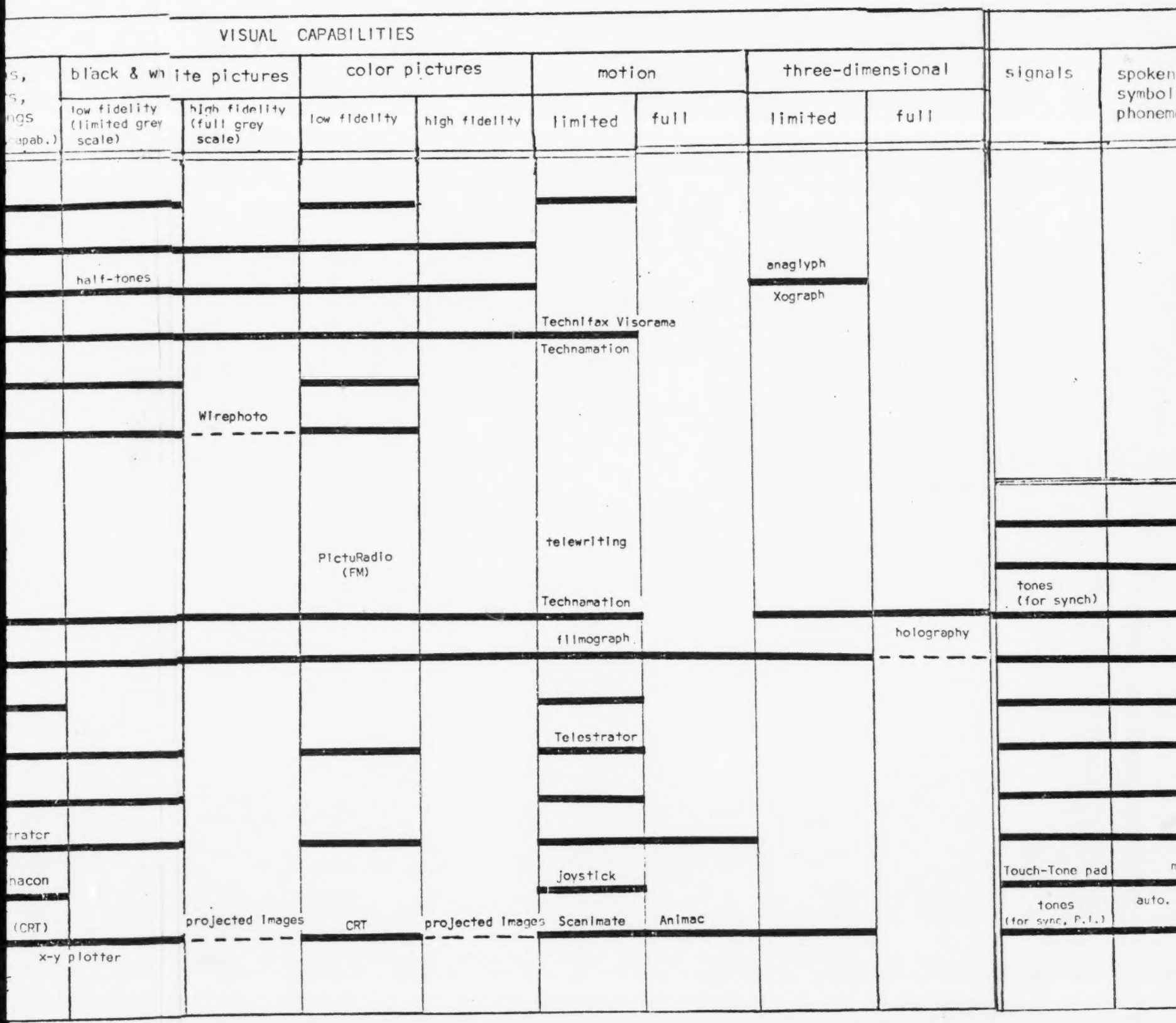



Figure 3: A Comprehensive Classification of Media and their Sensory Capabilities

| ensional | AURAL CAPABILITIES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| full | signals | spoken symbols, phonemes | spoken words | sustained speech (low-fidelity) | full monaural sound | | | stereophonic sound (2-channel) | multi-channel sound |
| | | | | | low fidelity | medium fidelity | high fidelity | | |
| | | | | | | | | disc | tape |
| | | | | | | | | | |
| | | | | | | AM | FM simplex | FM multiplex | |
| | tones (for synch) | | | | | FM-SCA | | | |
| holography | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | FM simplex | | |
| | Touch-Tone pad | microphone | | voice recognizers | | | | | |
| | tones (for sync, P.I.) | auto. speech generators | | voice synthesizers | sound synthesizers | | Moog synthesizer | | |
| | | | | | | | | | |

their Sensory Capabilities

Definitions of Specialized Terms and Trade Names

anaglyph: a system used in print and film media to provide the illusion of three dimensions. Left and right images are photographed through different color filters (often red and blue). The colored images are then superimposed in printing. When viewed through special eyeglasses containing filters of the same colors, a three dimensional effect is obtained.

COM: Computer-Output Microfilm, a means of recording digitally generated characters directly onto microfilm.

filmograph: a functional motion system providing the illusion of motion in film or filmstrip media by relative camera-film movement between frames.

Graphacon; Graf/Pen; etc.: Trade names for various forms of graphic data tablets, which digitize hand-written or hand-drawn information in real time through the use of a hand-held stylus and tablet containing a suitable x-y location sensory system.

kinescope: a means of recording a television program on film by focusing a motion picture camera on a television monitor.

Moog synthesizer: trade name for an advanced sound synthesizer capable of electronically creating any possible sound by means of plugboard and keyboard control.

PictuRadio: trade name (Educasting Division of Triangle Educational Services) for a system of transmitting still pictures on an FM subcarrier (SCA).

SCA: Subsidiary Communications Authority, an FCC designation for the use of FM subcarriers to transmit specialized programs, such as subscription music services, by frequency multiplexing on a regular broadcast signal. An SCA demodulator must precede the FM receiver to utilize SCA services.

Scanimate; Animac: Trade names of Computer Image Corporation for their advanced electronic animation systems.

Technamation; Visorama: trade names for functional motion systems employing Polaroid material in slides or transparencies. When viewed or projected through a rotating polarizer, an illusion of cyclic motion is created.

telecine or film chain: a means of using films on television by focusing a projector directly onto a vidicon television tube. Often, an optical multiplexer is employed with two motion-picture and one slide projector "multiplexed" by half-silvered mirrors onto the TV tube.

Telestrator: trade name for an advanced telewriting system used in conjunction with television to annotate programs locally. A conducting glass overlay on a horizontal television monitor is written on by a hand-held stylus embodying a finely pointed wire brush. A scan converter unit converts position-dependent voltages picked up by the moving stylus into a synched video signal.

Wirephoto: trade name for a telephotographic (facsimile) system using leased wideband telephone lines to transmit scanned photographs from a wire-service headquarters to subscribing newspapers.

Xograph: trade name for a graphic arts (printing) process employing the parallax panoramogram principle to provide an illusion of three dimensions without the use of special eyeglasses.

Figure 3: A Comprehensive Classification of Media and Their Sensory Capabilities (continued)

rationale for this is that the tactile, gustatory, and olifactory senses have not received the same attention as the more obvious visual and aural senses in the normal individual. However, more research and development using these senses is certainly warranted, particularly to provide handicapped persons with a more diverse information repertory. The stimulus categories are in columns, placed from left to right on the chart according to their degree of closeness to the real world. However, whereas Dale and Edling included real world stimuli in their categorizations, the stimuli types used here exclude that category.

In Figure 3, media are arranged in rows, roughly in order of technical complexity, which may not coincide with increased sensory capability. Four major media categories are indicated: visual, aural, audiovisual, and interactive. Within each category, there is a progressive arrangement of media by their usual mode of delivery--direct viewing; optical projection; and electrical or electromagnetic transmission. This last category is essentially a new one, made possible by the rapid development of computer-communications systems which are capable of providing immediate feedback to the learner. "Interactive" is intended to indicate capabilities beyond the usual two-way voice communication of the telephone system. However rudimentary capabilities of this sort are now in use on the telephone system, such as remote Touch-Tone access to computer-controlled voice-response systems. Also, the potential of Picturephone to provide more sophisticated man-machine interaction may result in services which go beyond its primary purpose of face-to-face communication. Certainly, the capability to interact directly and naturally with images and sound under computer control has great potential for education, and will be discussed in Chapter 3.

As is true in any attempt to place real-world systems into intellectually devised cateogries, Figure 3 cannot show all exceptions. The placement of media types in each of the four categories in a mutually exclusive manner is only indicative of their major applications. The placing of overhead transparencies and microimaging in the silent-medium category does not preclude using recorded or transmitted sound with them, nor is the placing of slides, filmstrips, motion pictures, and telewriting in the audiovisual category intended to imply that sound always must accompany them.

Examples of particular devices or systems are indicated on the lines at the intersection of certain rows and columns. These are to be regarded only as suggestive of the realization means of the medium in handling a particular sensory capability or range of capabilities, if so indicated.

Figure 3 makes it easy to study the range of all possible combinations of media with sensory capabilities. The extent of the lines indicates actual or experimental use of each medium in handling a range of capabilities. In addition to indicating the range of capabilities of each medium, it is easy to find which media can handle particular sensory capabilities by running down each column. Most of the media shown are in common use today, with the exception of still-picture television and Picturephone. Also, most of the capabilities of the interactive systems are not yet in common use.

It should be evident from the chart that communication media and their capabilities are not static. This is a time of rapid growth in the development of new media, and in the extension of the capabilities of older media. Thus, more diversity is to be expected,

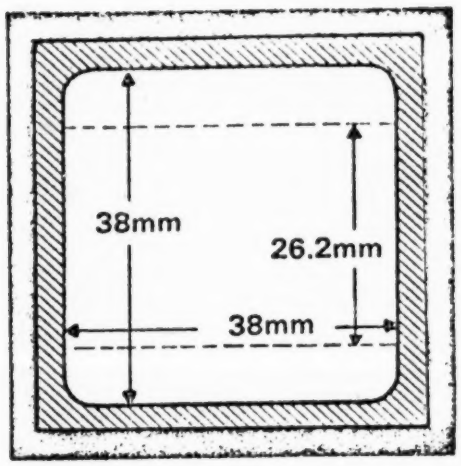
rather than, as some would hope, a moratorium on new developments so that some degree of stability and standardization might be experienced.

Media diversity is essential if the differing requirements of diverse user environments are to be met. For example, in projected media, characteristics which demand different capabilities include audience size; viewing location; illumination level; etc. On the other hand, there is little doubt that complexity of use and extreme diversity of equipment and media has hindered school use in the past.

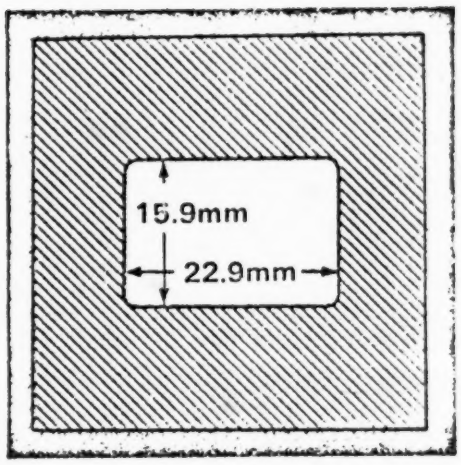
In the future, the action of the market should reduce the number of systems in common use, so that unnecessary incompatibility--such as exhibited by the still and motion-picture formats in Figure 4--is reduced. For example, there is no inherent reason why half-frame slides, single-frame filmstrips, and 35-mm motion picture frame dimensions cannot be made identical, nor why full-frame slides should use a different aspect ratio than all other oblong slide and film formats.

## 1.4 EDUCATIONAL COMMUNICATION SATELLITE SYSTEMS: PRECURSORS AND PREVIOUS STUDIES

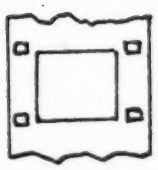
This section describes and evaluates a precursor of satellite-based television, and previous studies of the use of communication satellites for educational development in the United States. Nondomestic investigations are described elsewhere (5,6,7,9). An educational innovation of direct relevance to communication satellite utilization for U. S. education is MPATI, the Midwest Program on Airborne Television Instruction. Therefore, attention will be given at the outset to its development, and particularly to the difficulties which it encountered in attempting to become an educational facility enjoying long-term support and commitment.



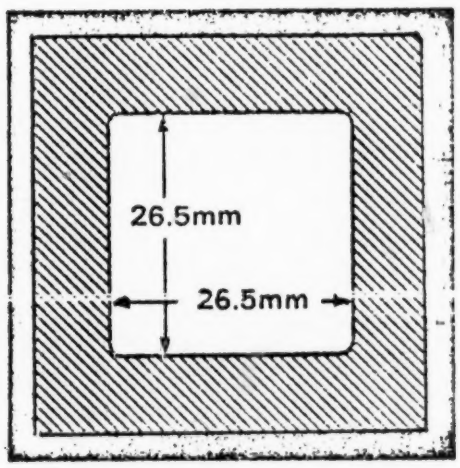

Super-Slide



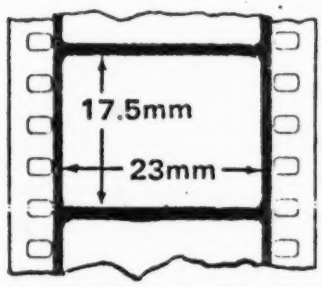

half-frame 35-mm slide



16-mm
motion picture
film
10.41 x 7.47 mm



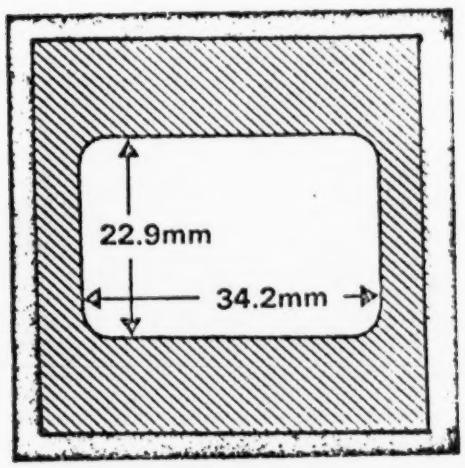

Instamatic slide



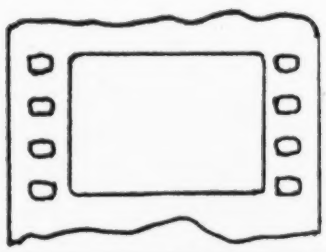

single-frame
35-mm filmstrip

Super-8
motion picture
film
5.39 x 4.03 mm

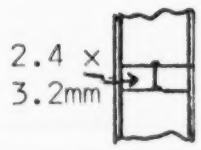
8-mm
motion picture
film
4.39 x 3.30 mm




35-mm slide



35-mm sound
motion picture film
22.05 x 16.03 mm




8.75-mm
EVR film

Figure 4: Still and Motion-Picture Media Format Diversity
(Note: projector gates lose about 5% of each dimension)

Following this, several paper studies of domestic educational communication satellites will be discussed.

1.4.1 MPATI: The Midwest Program on Airborne Television Instruction

On May 23, 1968, MPATI, a unique experiment in 2-channel airborne instructional television, came to an end--after seven innovative years (36) of broadcast activity. During the height of their activity, 1961-65, MPATI spent a total of $18 million (24). Although MPATI as an organization is still in business producing instructional TV programs and distributing videotapes of them nationally, they no longer distribute programs via their unique facility of airborne distribution (37).

A detailed study of MPATI including complete costs was done by Ivey et al. for Unesco (38). Also, a master's thesis on MPATI was written by Jameson (39).

According to Fall (40), MPATI's vice president, initial funding was obtained through the direct intersession of the Westinghouse Electric Company to the Ford Foundation. Together, they convinced the FCC of the viability of an experimental airborne television facility to serve education.

MPATI broadcast videotaped instructional programs over UHF channels 72 and 76 from a Douglas DC-6A aircraft flying in a figure-8 pattern 23,000 feet above eastern Indiana. Using five kilowatts per channel, MPATI programs could be received over parts of six states, covering a circular area 150 to 200 miles in radius. MPATI was originally assigned a total of twelve experimental channels, of which they used four--two in their main aircraft and two in an alternate aircraft. Thus, all four channels were never in use simultaneously. MPATI found that a double channel capability was inadequate to serve the educational

needs of their customers (40) , and so in January 1963, they petitioned the FCC for the permanent assignment of six channels in the uppermost portion of the UHF band (channels 70 through 83, 860 to 890 MHz).

The FCC held hearings over a period of two and a half years. The National Association of Educational Broadcasters (NAEB) was strongly opposed to MPATI's proposed expansion, claiming that all land-based UHF channels would be adversely affected. They recommended that available channels be conserved, and that local control of education be preserved (41, 42).

Fall believes that NAEB's opposition was largely a case of "not invented here", because individual members of NAEB have been enthusiastic about the introduction of satellite-based television. However, MPATI appeared as a direct competitor for scarce funds. They thought that the $15 million granted by the Ford Foundation to MPATI could have gone into ground-based ETV development, but there is no evidence that this would actually have taken place if MPATI had not existed.

Fall also believes that the FCC was trying to protect the upper range of the UHF band, and he claims that the FCC felt that MPATI's use of these channels would make it difficult, if not impossible, to permit the development of low-tower, low-power ground-based UHF television. However, the UHF channels originally assigned to MPATI have never been used for this purpose, and now it appears that this range will be reassigned to mobile services. This outcome was predicted in an MPATI-sponsored economic viability study by Steiner and Barnett (43).

Thus, the Commission turned down MPATI's petition, and furthermore disallowed the continued use of the UHF channels previously assigned to MPATI. Instead, they offered MPATI six channels in the Instructional

Television Fixed Service (ITFS) band. This band comprises thirty-one 6 MHz channels from 2500 to 2680 MHz, with power usually limited to 10 watts per channel (44).

MPATI thereupon made an unsuccessful attempt to obtain funds for an ITFS feasibility study. This failure, coupled with a drastic drop in new members--who were uncertain over what equipment they would need--impelled MPATI's membership to recommend terminating airborne telecasting at the end of the 1967-68 school year.

It is doubtful if the failure to get additional channels is the whole reason for MPATI losing its broadcast capability. According to Richard Hooper:

> "The newer media are not present in the inner sanctuary of curriculum decision-making...Until the educational technologist can fight his way into the departmental meetings and curriculum committees, whatever he has to offer and however much sense it may make will, at best, be seen as only a frill. In 1967 B. Bohnhorst, director of the Midwest Program on Airborne Televised Instruction (sic) stated in an interview one reason for MPATI's failure...as follows: 'MPATI from the start was not lined up with the power structure.'" (25)

Robert Glazier, executive director of KETC, the St. Louis area's VHF educational television station, believes that a good deal of MPATI's difficulties can be attributed to their lack of control over the very large geographical area which they attempted to serve. Their backup services, particularly printed materials, were insufficient, and--most important--they couldn't collect needed revenue from many schools which "free-loaded" on the service (45). Fall confirms that this "pirating" was a big problem. An informal survey conducted in Ohio during the last phase of MPATI's airborne experiment found that more than 300 school systems were using MPATI programs without paying for them (40).

Of course, much the same thing could be said of the public which benefits from educational television programming during non-school hours. In 1966, the American Research Bureau estimated that 17,300 homes were reached by KETC on an average day, and that 91,000 households viewed the station at least once per week (46). In contrast to this, only about 5,000 households were contributing to KETC--by means of a voluntary annual membership of $10 or more.

In fact, KETC could not exist without the financial support of local school systems, which have provided almost two-thirds of the station's income. Participating schools pay $1.25 per pupil annually, and for this modest sum receive many printed materials which are essential to provide good briefings for the televised courses. KETC's income was $471,351 in 1967-68 (47) and $621,690 in 1968-69 (48), out of which school services accounted for $319,010 and $367,598, respectively. Their instructional programming for 1970-71 has been made precarious by a 50% cut in funds for this service from the St. Louis city schools.

The likelihood of MPATI's experience being repeated with satellite-based educational technology is high, unless those responsible can provide service on a viable political and economic base.

It should be kept in mind, however, that traditional formal education is not the only potential customer for the tremendous distributional power of communication satellites. Many educational organizations serve more specialized needs, including handicapped, vocational, adult, and continuing education and training.

An excellent survey of the innovative work of our private vocational schools has been done by Belitsky, who points out that:

> "The achievements of proprietary schools have remained unknown because they have been virtually ignored by academic educators and the U. S. Office of Education. In addition, the owners and administrators of the private schools are rarely scholars and there have therefore been only limited attempts to even describe the schools' operations and accomplishments." (49)

The failure of MPATI went beyond the technical and the political into the economic--they did not have any means of insuring support from those who used the service. This experience suggests that if a communication satellite is launched solely for educational use, or even if it only provides channels for such use in a satellite launched for other applications, the ground set-up deserves the most intensive attention. In the initial stages, ground facilities may have to be subsidized by federal, state, or local funds, but it seems essential to involve schools from the beginning in a direct way--by having them pay a reasonable use fee on a per-pupil or per-capita basis for services received.

In view of MPATI's experience, non-paying users shouldn't be able to receive these services at all. If anyone can tune in satellite-borne programs without paying for them, there is little inducement on the part of those who do pay to continue their support. Technologically, this problem might be solved by scrambling the signal, using techniques worked out for subscription (pay) TV.

### 1.4.2 Previous Studies of Domestic Educational Communication Satellite Systems

EDUSAT is a preliminary design study for an educational television satellite system intended for use in the U. S. in the mid-1970's. This

concept was developed in an ASEE*-NASA Summer Faculty Fellowship Program in Engineering Systems Design (8). Dr. Emil Steinhardt and 15 faculty fellows from business management, economics, education, engineering political science, psychology, and systems analysis did this study over an 11-week period.

EDUSAT proposed providing satellite services in three areas: public television (PTV), special television (STV), and instructional television (ITV), using both distribution and direct-broadcast satellite modes. Four full-color television channels would be provided, with programs originating from any of the four ground facilities--one each in the east, the midwest, the far west, and the south. One of the channels would broadcast direct to home receivers.

The proposed uplink frequency band was from 8.025 to 8.4 GHz; the downlink frequency band from 7.3 to 7.75 GHz; and the direct broadcast would be in the 800 to 806 MHz band (UHF). A single satellite would be used not only to service the entire continental United States, but also Alaska and Hawaii, via separate beams.

The EDUSAT report concentrates on the engineering design and cost estimates of such a satellite; program production problems and costs are not considered (see Table 2). Satellite distribution linkage would have a capital cost of $96 million and an annual cost of $11 million, including the four sending stations. Organizations desiring to receive the weaker 7.3-GHz signal would have to invest $3,000 per site, and homes wishing to receive the stronger 800-MHz signal would have to augment their receivers at costs ranging from $100-$500.

* American Society for Engineering Education.

Table 2: Summary of EDUSAT Proposal

(all costs in millions of dollars, except per unit costs)

| | | | Capital costs |
|---|---|---|---|
| **Mechanical** | | | |
| launch (mid '70's) | 2 Atlas-Centaur @ 14.5[1] | | 29 |
| satellite[2] | 2 @ $19, + $23 for R & D | | 61 |
| power | 10 kw from 1300 sq. ft. of solar cells | | |
| weight | 2500# | | |
| **Electronic** | | | |
| no. & type of channels | 4 color TV, TASO Grade 2 (fine) | 1 direct B/C | |
| bandw./channel | 36 MHz | | |
| total bandwidth | 200 MHz | | |
| **uplink** | | | |
| transmitters | 4 ground stations[3], @ $0.6, each w. 2 color VTR's @ $.07 per VTR | | 6 |
| power | 10 kw/channel each (Klystron) | | |
| frequency | 8.025-8.4 GHz | | |
| strength | ERP 101 dbw; 95 dbw/channel | | |
| ground antennas | 4 of 30' dia. in each loc'n. @ $0.1, inclu. towers | | 0.4 |
| sat. receiving ant. | horn, of ~ 17° beam width | | |
| **downlink** | | | |
| | distribution | direct B/C[4] | |
| transmitter | | | |
| modulation | FM | FM | |
| power | 533 watts/channel (input) | 3650 watts (input) | |
| frequency | 7.3-7.75 GHz | 800 MHz | |
| sat. transm. ant. | 3.1° (major axis) ellip. parab. | 27' (major axis) ellip. parab. (3° x 7½°) | |
| **ground** | | | |
| | distribution | direct B/C | |
| antenna | 15' parab. movable (0.6° beamw.) @ $2500-3500/site | 5' parab. fixed (16° beamw.) @ $50/site | |
| receiver | 7.3-7.75 GHz → 700-900 MHz preconverter | UHF with FM → AM-VSB cnvrtr. | |
| | @ $3500-4000/site | @ $100-500/site | .016[5] |
| **Other** | | | |
| program production | (est. $30,000-50,000/program hour) | | |
| **Total capital costs**, including 4 ground stations: | | | $96.42 |
| **Annual operating costs**,[6] 24 hours a day: $19 | | | |

Abbreviations: B/C - broadcast; VTR - videotape recorder; ERP - effective radiated power

[1]including range costs
[2]Five-year lifetime; equatorial synchronous orbit
[3]Los Angeles, San Francisco, Chicago, Houston, Boston-New York-Washington
[4]included in satellite cost
[5]Not including direct B/C receiver conversion and antenna costs
[6]Not including program production costs

The EDUSAT report contrasts these satellite distribution costs favorably against those stated in the Carnegie Commission report on Public Television, in which annual costs of land connections between the 380 existing ETV stations were estimated to be $17 million (50).

As in several other attempts to do a systems analysis and design for educational communication satellites, EDUSAT's primary emphasis was on the technical aspects, which are relatively easy to obtain and quantify. The organization chart for a proposed educational satellite corporation was also sketched out, and some attention paid to the political problems of instituting such a corporation. However, because of the differing objectives of PTV, STV, and ITV, little attention was paid to the problems of working with school systems. Furthermore, little if any effort was devoted to analyzing critical software areas, such as program quality and availability, and teacher requirements.

Recently, a proposal for "An Instructional Communications Satellite System for the United States" has been made by E. M. Sheppard (51). Educational television, computer-assisted instruction, and "data retrieval" for grades K through 12, in 110,000 schools would be part of a system involving seven synchronous satellites, using twenty narrow beams.

Sheppard envisions dividing the continental U. S. into 15 regions by school population. Regional centers would send programs to the satellites over a 40-MHz-wide channel in the 30-GHz region, and satellites would rebroadcast this channel in the 18-GHz region. In addition, individual schools would use a 2-MHz-wide uplink bandwidth for data return in the 30-GHz region. He estimates that the ten-year cost of such a system at 4.3 billion dollars, which would be only about $8 per

student per year, and states that: "If one triples this figure to account for software and maintenance, the $25 cost is quite reasonable in terms of the typical expenditure per student per year...[which is] $500." (51).

Sheppard's proposal is predominantly concerned with hardware and media requirements, with little consideration of software. However, some attention is given to political and social factors: "It would be essential that the network be capable of highly individualized control by state and local school districts." (51) Sheppard uses this to justify equipopulation regions for his frequency assignments. However these boundaries neither utilize satellite beam shapes effectively nor satisfy the demand for local control. For example, one region covers the five states of Nevada, Utah, Colorado, Arizona, and New Mexico, while others are restricted to large single states whose population requirements are hardly homogeneous, such as California and New York.

A two-part study by 1969 undergraduate fellows of the Institute for Creative Studies (ICS) has been published on the "Use of Satellite Technology in Education in the Continental United States" (52). The first part is an overview, which asks significant questions about the relation of satellite technology to education. The second part relates their experience with three questionnaires devised to find out what educational users might do with satellite channels. These questionnaires were pilot-tested on small groups of educators.

The first questionnaire dealt with present and future educational user requirements, and was of a multiple-choice nature. Of the results of this questionnaire, the authors state that: "It was clear that the

uncertainty of the yet to be developed educational technology associated with satellite technology made it virtually impossible even to begin to guess at answers to the questions of cost let alone of educational financing, feasibility, and administrative alternatives."

The second questionnaire, on the content of educational processes, particularly degree of interaction, type of reinforcement, and motivation, allowed open-ended responses. The third questionnaire explored attitudes toward the adoption of instructional technology, and needs that might be associated with satellite technology. Results of the second and third questionnaires were not reported. Recommendations were made that a single revised questionnaire be presented to a stratified random sample of U. S. educators. It is not known whether any of these recommendations have been followed up. However, in industry, where similar market research techniques are used, it is particularly difficult to determine the potential market size and distribution for a new and untried product or service. In such cases, newer techniques, such as the Delphi method (53, 54) and its variants (55), are highly desirable to weed out the sheer guesses which many responders use when confronted with the unknown.

## 1.5 SCOPE OF STUDY

In what follows, the characteristics and applications of technology which might be utilized in an educational communication satellite system are analyzed in detail. Chapter 2 is devoted to a technology of particular interest, still-picture television, in which the full-motion capability of television is given up in favor of bandwidth conservation and greater program diversity.

Chapter 3 provides an overview of computer-assisted instruction, and analyzes a computer-controlled instructional television CAI system in detail. Also, interactive graphic display systems are discussed, particularly as related to television.

Chapter 4 discusses the complex trade-offs between communications and transportation as applied to the delivery of educational materials. A number of technologies which have present or future promise are described in detail. The use of communication satellites to electronically distribute printed educational materials is considered, with emphasis on facsimile technology. New developments in microimaging technology for physical delivery of the same class of materials are analyzed, and potential interfacing with television and computer systems is discussed. For nonprint materials, such wired-communications technologies as Picturephone and CATV are described in both competitive and cooperative relationship with satellite-based communication systems. Finally, a detailed analysis of the most promising technologies of physical distribution for nonprint educational materials is given, centering on the promise of cassette systems for audio and video programs, and the video disc system.

Chapter 5 expands on the role of satellite technology in conjunction with communication media and educational technology. A hypothetical schedule for utilization of an educational satellite is proposed.

# 2. STILL-PICTURE MEDIA FOR INSTRUCTION

## 2.1 INTRODUCTION

In this chapter, the needs of the learner will be examined and related to media characteristics. It will be seen that the capabilities of full-motion television are not always needed in an instructional setting, and that when this is so, the very large bandwidth requirements of TV may be utilized alternatively for transmitting a multiplicity of other types of instructional programming. Such programs may have varying stimulus content, depending upon the requirements of the instructional sequence. Some examples are:

1. audio-only programs;
2. audio, plus printed material sent via facsimile;
3. picture sequences (analogous to silent filmstrips);
4. still-picture television programs (analogous to sound filmstrips).

Of these possibilities, still-picture television receives the greatest attention in this report because its capabilities come closest to matching those of full-motion television, and because rationale and techniques for its use have not received adequate attention, except possibly in space exploration (56-58). An analysis of the use of still-pictures for educational television has been given in a series of articles by Hall (59), and Bretz has devoted a section of his report on communication media to audio-still-visuals (10).

## 2.2 SENSORY CAPABILITIES OF EDUCATIONAL MEDIA

Many educational communications proposals concentrate on the use of television as the prime medium. However, there are other possible uses of the capabilities provided by communications satellites. One recent attempt to make a case for other broadcast media is that of Jamison, Jamison, and Hewlett (60). They claim that the relationship of cost to benefits greatly favors radio over television.

The history of educational radio has been documented elsewhere (61, 62). Although it never attained widespread acceptance in the United States as a significant educational medium, in many other countries, radio has made an important contribution. For example, the British Broadcasting Corporation has been using shortwave radio to teach English throughout the world (63), and in conjunction with other media and personnel, radio has been instrumental in teaching illiterates to read and write their own language in such countries as Colombia (64).

However, despite the attractiveness of radio in terms of simplicity and low cost, its necessary concentration on a single sensory channel or dependence on supplementary aids falls short of an optimum learning situation in many instances.

For example, in a reading comprehension experiment, Travers and Jester found no significant differences among audio, video, and audio-video (AV) versions at presentation rates up to 200 words a minute. But as the speed of presentation was increased beyond this, auditory comprehension fell off much more rapidly than video. However, the AV presentation showed an increased advantage over either audio or video

presentations alone (65). Also, Travers notes that in an AV presentation, each subject is free to choose--albeit unconsciously--the sensory modality most effective for him. Thus, a group of subjects receives information better when a variety of sensory modes are employed than when the information is presented through a single sense, which would tend to penalize some individuals. This latter finding should be useful in training disadvantaged students, particularly those lacking good reading skills.

In designing instructional systems, it is wise to take into account the widely different learning capabilities of students. Also, a variety of presentation methods may be required to meet the instructional objectives of a subject area. Although large portions of such subjects as music and spoken-language learning are best appreciated aurally, a subject such as painting demands high-quality visuals. However, when discussing a painting with a student, it would hardly be a good solution to present the discussion in textual form when his eyes should be on the picture, so that audio is an essential supplement. Similarly, in teaching reading, if the objective is to relate the written language to the spoken language, it should be beneficial to see textual and illustrative material while listening to the spoken word.

A detailed breakdown of stimulus dimensions for learning was devised by Edling (27), who characterized media by their degree of closeness to direct experience with people or with things. In programmed-learning terms, this is equivalent to increasing or decreasing the number of cues (see Figure 1). Given such a model, one needs to specify his educational objectives so that he can decide from moment to moment in a

learning experience whether a greater or lesser number of such cues are desired. That is, the educational advantages of adding an increment of reality must be balanced against a corresponding cost increment.

Ideally, eye and ear should provide complementary learning experiences. However, a single sensory mode is seldom pushed to its limits. This is apparent in cases where information can be assimilated at much higher rates than it can be presented. For example, trained persons can readily attain rates of 500 to 700 words per minute in silent reading, and the ear is capable of accepting information at higher rates than a lecturer is capable of speaking, as evidenced by numerous experiments in "speeded speech" (66-68).

There is reason to believe that the ultimate information-input rate is not limited by either of the main human sensory organs, the eye or the ear, but only by neural processing mechanisms in the brain (69). If a single sensory mode is being used efficiently, other sensory modes seem to become locked out to some degree, which aids concentration. However, particularly with children whose early learning experience has been influenced by television, there is strong expectation that both senses will be used.

In Sections 2.3 and 2.4, the still-picture medium is examined in detail. Requirements for still-picture transmission will be shown as falling between radio and full-motion television in terms of bandwidth utilization.

## 2.3 THE FILMSTRIP MEDIUM AND ITS USE IN TEACHING MACHINES

The prime instructional medium currently employing still pictures is the filmstrip. Filmstrips have been used far more effectively in

industry than they have in education, particularly for sales presentations (70). However, prospects for their fuller utilization in education have increased greatly in recent years.

In his forward to the first edition of NICEM's* "Index to 35-mm Educational Filmstrips" (71), VanderMeer describes five characteristics that are largely responsible for the unique contribution filmstrips have made to education during the past 50 years:

1. Images can range in complexity from simple line drawings to full-color high-quality photographs.
2. Various relationships are possible among three stimulus types: pictures, words, and sounds.
3. Stimuli occur in a fixed and preprogrammed sequence.
4. Simple to use by individuals, small-groups, or classes.
5. Presentation pace is variable and under the control of the user.

An important additional point is that the silent filmstrip can be made independent of verbal language of any sort--written or spoken. Thus, the filmstrip medium has the potential to provide truly international communication, if communication can be done entirely in pictorial terms.

In cases where the synchronized-sound capability of the filmstrip medium is employed, the fifth, and most individualized characteristic, is sacrificed, because sound filmstrips must proceed at a fixed and preordained pace. However, within limits the pacing of the sound can

* National Information Center for Educational Media, University of Southern California.

be varied, and it is much easier to do this with filmstrip than with motion-picture film, because the progression of the pictures can be controlled by signals accompanying the audio information. Also, sound compression techniques can provide separate control over pitch and tempo, so that audio information may be squeezed or stretched out in time to match variable picture pacing (68).

Table 3 compares the physical and utilization characteristics of sound filmstrips with the sound motion picture film. It is apparent that considerable savings in size, weight, and distribution costs are possible using the filmstrip medium, if film's unique depiction of motion can be sacrificed. At the same time, more flexibility in use may be attained.

The flexibility of filmstrips is particularly important if it is desired to individualize instruction--and individualization is peculiarly difficult to accomplish in the traditional classroom situation. If the student uses a filmstrip in a viewing device under his own control, he need miss none of the material because he cannot keep up; on the other hand, the student who learns rapidly can race ahead. Furthermore, if the creator of the filmstrip has done an innovative job, and not just adapted a story or instructional sequence for another medium, he may lessen the time in which it takes to learn an instructional sequence.

Also, if the sequence is designed to require some sort of overt response to each frame--a "programmed filmstrip"--retention of learning may be enhanced. National attention has been focused on this type of filmstrip recently in connection with the first educational performance

Table 3: Characteristics of Film and Filmstrip Media

| | Nontheatrical Motion Picture Films | Sound Filmstrips | Film/ Filmstrip Ratio* |
|---|---|---|---|
| Physical: | | | |
| width | 16-mm, perforated | 35-mm, perforated | 1:22 |
| length | 100' to 1600' on reel (800' typical) | 3' to 9' strip (4' typical) | 200:1 |
| total material | 800' x 16 mm = 6000 sq. in. | 4' x 35 mm = 66 sq. in. | 91:1 |
| frame size (on film) | 10.22 x 7.43 mm | 23 x 17.5 mm | |
| image area (on film) | 75.83 sq. mm | 402.5 sq. mm | 1:5.3 |
| frame size (projected) | 9.65 x 7.21 mm | 22.5 x 17 mm | |
| image area (projected) | 69.58 sq. mm | 382.5 sq. mm | 1:5.5 |
| aspect ratio | 4:3 | 4:3 | |
| color | yes | yes | |
| sound | optical (and/or magnetic) | 7" 16-2/3 rpm or 12" 33-1/3 rpm phonorecord (or 3-3/4 or 7-1/2 ips magnetic tape) | |
| film speed | 24 fps (sound); 16 fps (silent) | variable (dependent upon signals in sound recording) | |
| Utilization: | | | |
| typical running time | 22 min. | 7 to 15 min. | |
| typical reel size and footage | 10" dia. reel holds 800' | 4' strip, 50 frames | |
| packaged dimensions | | 1-1/2" dia. x 1-1/2" height = 1-3/4 sq. in. x 1-1/2" = 3 cu. in. for coiled film in can | |
| | | 7" x 7" x 1/8" = 6 cu. in. or 12" x 12" x 1/8" = 18 cu. in. } for record | |
| | 10" x 10" x 1-1/4" = 125 cu. in. | Total, packaged: 9 to 21 cu. in. | 14:1 to 6:1 |
| packaged weight | | 1/2 oz. for film in can<br>3 or 9 oz. for record in jacket | |
| | 3 lb. for 800' reel | Total, packaged: 6 to 14 oz. | 8:1 to 3.4:1 |
| shipping cost + | 24¢ + 30¢ insur. = 54¢ (spec. 4th cl.) | 12¢ to 28¢ + 20¢ insur. = 32¢ to 48¢ (3rd class) | 1.7:1 to 1.1:1 |
| | or $1.90 + 30¢ insur. = $2.20 (air mail) | or 80¢ + 20¢ insur. = $1 (air mail) | 2.2:1 |

*The higher the ratio, the greater the advantage of the filmstrip medium, except in image area where the reverse is true.

+These costs can be greatly reduced if the library mail rate can be used (only applicable if the material is sent to or from an educational or non-profit organization). The current library rate is only 5¢ for the first pound, and 2¢ for each additional pound without regard to zone. Therefore, a 3-pound film could be sent for 9¢ and a filmstrip for 5¢, both plus insurance.

Table 3: Characteristics of Film and Filmstrip Media (continued)

| | Nontheatrical Motion Picture Films | Sound Filmstrips |
|---|---|---|
| Unique features: | 1. persistence of vision provides illusion of motion, permits full animation, slow-motion, time-lapse, and other special effects. | 1. program can be stopped, response elicited, and restarted; preferred medium for teaching machine use. |
| | 2. highly motivating; enhances affective learning. | 2. motivational when properly done; primarily for cognitive learning. |
| | 3. preferred medium for TV interfacing. | 3. lends itself to multiscreen presentation. |

contract, with the Texarkana school system (14). There, Dorsett Educational Systems, Inc., has used their low-cost audio-visual teaching machine (AVTM) to motivate and instruct underachieving students. Dorsett's M-86 AVTM incorporates a rear-screen projection system and phonograph in a compact device which looks like a portable TV. It uses standard 35-mm filmstrips, and 16-2/3-rpm long-playing records with 30/50 Hz control signals which are used to stop and advance the filmstrip automatically, and to evaluate push-button multiple-choice responses.

The 30/50 Hz system was originally developed by DuKane, Inc., (72) for pulsing the advance mechanisms of their sound-filmstrip projectors. The 50 Hz is used as a "lockout" frequency, and the advance mechanism is only triggered when this inaudible tone is interrupted by one of 30 Hz, sustained for 1 to 1-1/2 seconds. At least 1-1/2 seconds more must elapse before the mechanism can be retriggered. The 50 Hz signal is unnecessary if audiotape is used instead of LP records. Dorsett has added a stopping capability to this system (by dropping the 50-Hz lockout), and uses short bursts of 30 and 50 Hz tones to set multiple-response circuits as the record coasts to a stop (73).

As of the end of 1970, the M-86 sells for $200, plus a mandatory first-year maintenance contract of $96. Instructional programs are available for $150 up per set of 8 to 15 filmstrip-record units, with individual programs priced from $10 to $15 each. These prices are slightly above ordinary sound filmstrips of comparable length, but include start-stop-response signals on the records. Systems of comparable capability have been marketed by other manufacturers for

the educational market, but at somewhat higher prices. For example, the Viewlex AVS-10 audiovisual teaching machine costs $350, and Borg-Warner's System 800 costs $500.

Systems which lack the multiple-response capability are more widely available. For example, Audiscan, Inc. has a rear-screen unit which uses special cartridges. Each cartridge contains a continuous loop of 16-mm film of up to 225 frames, and a continuous loop of 1/4-inch audiotape holding up to 25 minutes of sound. In their model TSM, tone bursts on the tape are used to advance (500 Hz) or stop (2,500 Hz) the filmstrip. However, the only response possible to the learner is to push a button to restart the program. The Audiscan TSM sells for $345. Cartridges cost $10 each, including 10 feet of processed 16-mm color film stock and 300 to 400 feet of audiotape. Prepared programs packaged in these cartridges cost from $45 to $100 each. Audiscan, DuKane, La Belle, and other manufacturers of restartable sound filmstrip packaged systems have concentrated their marketing efforts on the business and industrial training markets.

Unfortunately, with the exception of the Dorsett system, all of the above systems are mutually incompatible with the conventional sound-filmstrip medium. Undoubtedly, this has been a considerable deterrent to their acceptance in the educational marketplace.

2.3.1 Filmstrip Versus Film: Economics and Markets

The sound filmstrip medium in its conventional form employs 35-mm color film, with sound on a phonograph record which also contains either inaudible control tones for automatic frame advance of the filmstrip projector, or audible advance signals. The detailed analysis of

filmstrip costs and markets as compared to 16-mm sound motion pictures made in this section (see Table 4) provides an indication of possible savings which may be realized by still-picture television compared to full-motion television.

It might be expected that filmstrips, which use only one percent as much film material as do motion pictures, should offer comparable savings in their over-all economics. However, such is not the case. Hope (18) found that in 1968 the average production cost of non-theatrical sponsored motion pictures was $19,500 while the average sponsored sound-filmstrip production cost was $10,300, or more than half as much (see Table 5). A sponsored film is one produced by an organization to promote a product or service. However, such films do not usually use the hard sell, and may be artistic triumphs, such as Robert Flaherty's "Louisiana Story" which was sponsored by the Standard Oil Company. From Hope's data, an average market figure for all non-theatrical films of $12,660 can be implied. A figure for films produced strictly for instruction cannot be so derived, but their production costs are probably less than half that of sponsored films.

There is a much larger savings in making and distributing filmstrip prints as compared to film prints. Andereck has stated that the typical 10-minute 16-mm color sound film purchased by the Cooperating School Districts of the St. Louis Suburban Area cost them $120 to acquire (74). However, sound-filmstrips can be purchased for one-fifteenth as much.

A school can diversify its audiovisual program material by building up its own library of filmstrips, whereas an equivalent library of films would be prohibitively costly. However, looking only at costs,

Table 4: U. S. Market for Film and Filmstrip Media*

| | 16-mm sound films | | 35-mm filmstrips | |
|---|---|---|---|---|
| | all markets | educational portion | all markets | educational portion |
| no. of titles available (est. on 5-yr. lifetime) | 35,000 to 50,000 | ~10,000 (75) | ~40,000 (69) (only ~15% are sound filmstrips) | 21,500 (77) |
| no. of prints owned* | 5 to 7.5 million (@ 150 prints/title) | 1,315,000 (76) (≅ 130 prints/title) | ~50 million (@ 1500 prints/title) | 21,700,000 (76) (≅ 1000 prints/title) |
| est. market value of owned** prints | $1 billion to 2 billion (@ $200 to $300/print) | $150 million to $300 million (@ $120 to $240/print) | ~$400 million (@ $8/print) | ~$100 million (@ $5/print)++ |
| no. of new titles produced 1968 | 13,750 | 1700 | ≅4,000 (>50% sound) | ≅2,000 |
| total sales, 1968 | $453.6 million+ | $44 million (for all types of motion-picture films) | $51 million ($20 million silent) ($31 million sound) | $26.4 million ($17.2 million silent) ($ 9.2 million sound) |

* All figures are given by, or derived from Hope (18) , except where otherwise indicated.

** Schools generally rent films, but buy their filmstrips; this may account for the greater educational share of filmstrip prints owned (~40% of total filmstrips owned in all markets) versus films owned (~20% of the total).

+ includes $3.8 million for shortfilms, which are defined as film loops or single-concept films, and are usually 8mm.

++ Silent filmstrips predominated in the past, particularly in education.

Table 5: Unit Production, Printing, and Distribution Costs of Film and Filmstrip Media

| | Film | | | | | | | | Sound Filmstrip | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | sponsored | | | all sources | | | educational | | | sponsored | | | educational | |
| | No. of prints/ title+ | $1000 | % | No. of prints/ title | $1000 | % | No. of prints/ title | $1000 | % | No. of prints/ title | $1000 | % | No. of prints/ title | $1000 | % |
| production cost | | 19.5* | 41.1* | | 12.66 | 38.7* | | 6.1 | 28.0* | | 10.3* | 59.0* | | 3.0 | 37.5 |
| cost of making release prints | 150 | 13.0 | 27.4* | 125 | 8.81 | 26.9* | 100 | 6.5 | 29.6* | 2000 | 5.15 | 29.5* | 1500 | 3.5 | 43.8 |
| distribution cost** (over 5 years) | | 15.0 | 31.6* | | 11.26 | 34.4* | | 9.2 | 42.4* | | 2.0 | 11.5 | | 1.5 | 18.7 |
| Total cost | | 47.5 | 100.0 | | 32.73* | 100.0 | | 21.8 | 100.0 | | 17.45 | 100.0 | | 8.0 | 100.0 |
| Total cost per release print | | $317 | | | $262 | | | $218 | | | $8.73 | | | $7.50 | |

* These figures are given directly by, or derived from Hope (18). Others are based from these, or estimated by simple proportion. For educational films, a total cost 1/3 less than those from all sources has been assumed. For educational filmstrips, a production cost 70% less, and a total cost 50% less than sponsored filmstrips has been assumed.

** The distribution cost per showing may be estimated as follows: If each of the 125 release prints (second film column) are shown 75 times over a 5-year lifetime, there would be 9375 showings, or $1.20 per showing. In the case of filmstrips, it is assumed that most are sold outright, and that the distribution cost is $1 each for handling, mail, and insurance.

+ The number of film release prints per title is based on 1954 data in reference (78), taking the median for a 16mm color film to be 100 prints, and scaling it up 25% to take into account the growing popularity of films. Then, the sponsored prints are assumed to be 20% greater, and educational films 20% less than the all-sources figure of 125 prints/title. The number of filmstrip release prints per title are upwards estimates from a figure of 1000 for existing (mostly silent) filmstrips, derived from references (76, 77). For educational filmstrip release prints today, this figure is increased 50%, and for sponsored filmstrips, 100%. These increased print production estimates are based on the increasing proportion of filmstrips being made with sound, and a corresponding increase in their popularity. Hope (18) stated that: "the [1968] sound filmstrip...market for the business category had the greatest rise of all product lines, a 146% gain [over 1967]."

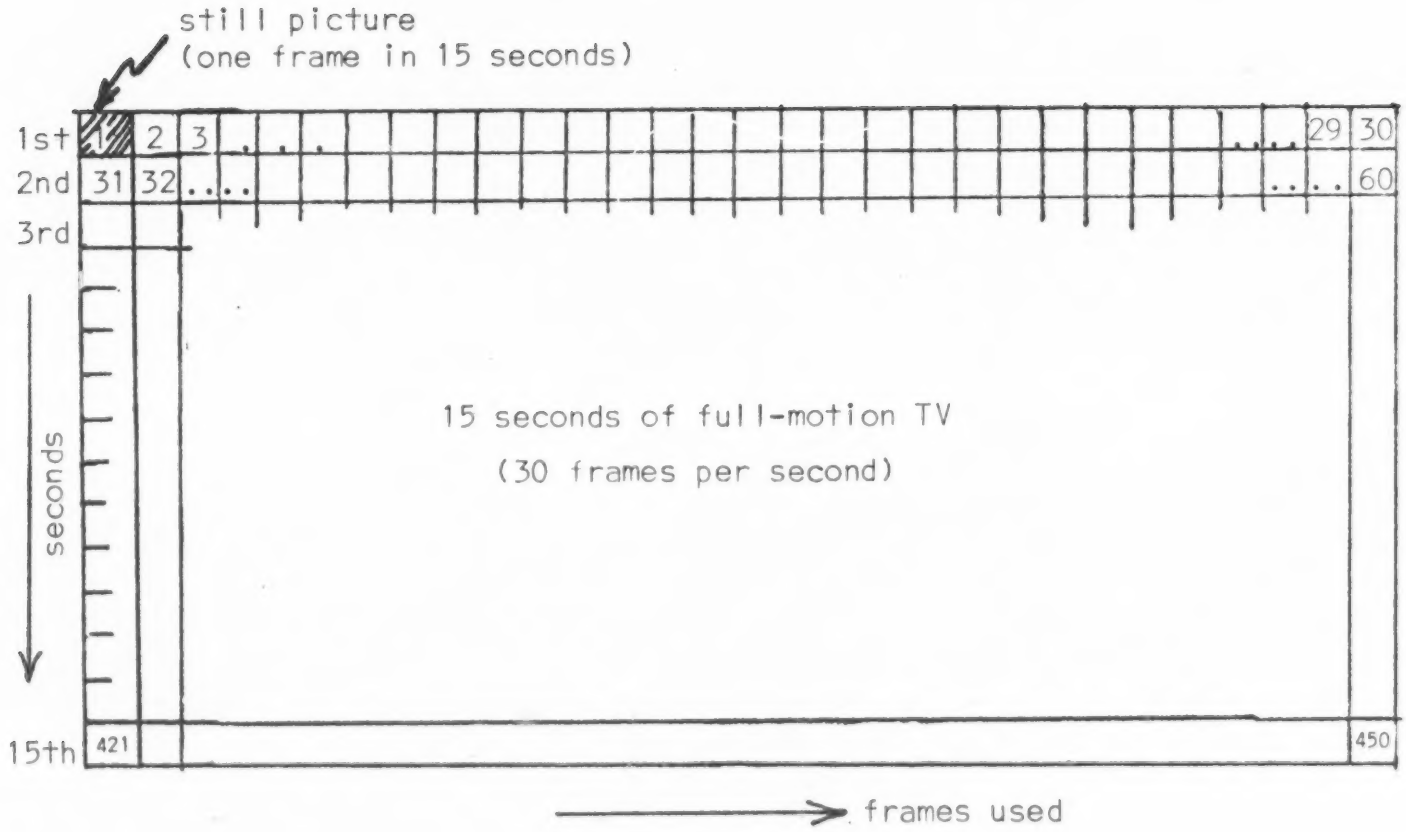
it should be pointed out that while filmstrips are from ten to thirty times cheaper to acquire than motion pictures, printed booklets of similar content can be obtained for a tenth to a twentieth the cost of filmstrips.

What should be emphasized in these comparisons is that the great variety of media which have stood the test of time in the marketplace have a place in education. In particular, pictures--not only filmstrips, but slides, opaques, and other visuals--have a vital role to play in instruction, especially when coordinated with sound. New ways of distribution should enhance their utility. For example, satellite-based television, regarded as a universal communications channel, may be used to distribute such programs and materials on a nationwide and even worldwide basis.

## 2.4 STILL-PICTURE TELEVISION

The basic rationale for considering electronically transmitted still-pictures for education is that existing communication bands are becoming increasingly more crowded, and constitute a scarce resource which should be used as efficiently as possible (79). Full television capability is wasteful of this scarce resource. Even though there is very little change from one television frame to another, a complete picture must be re-sent 30 times every second to give the appearance of motion and to avoid flicker (see Figure 5).

Furthermore, for many instructional purposes, still pictures with sound can be as effective as motion pictures (80) Only when students are studying such topics as athletics, machine dynamics, or other phenomena which change rapidly in time, must motion be needed for




If the average viewing time of a still-picture is taken to be 15 seconds, during the same time, full-motion television would use up:
30 frames/sec. x 15 seconds = 450 frames

However, it should be pointed out that this comparison does not take into account the disparate requirements of still-picture television for audio bandwidth (see Section 2.4.2)

Figure 5 : A Graphic Depiction of the Relative Bandwidth Requirements of Full-Motion and Still-Picture Television

full meaning (81-82). However, in a large part of instruction, it is unnecessary to provide the illusion of motion, and in such cases, the pacing forced by a fixed progression of 30 frames a second may be disadvantageous.

Transmission requirements for still-picture television fall between those for high-fidelity FM sound (15 KHz, transmitted within a 200 KHz wide channel) (83), and commercial full-motion TV (4.2 MHz for video plus 15 KHz for FM sound, transmitted in a 6 MHz channel) (83). Any system for transmitting still-picture television programs should be compatible with full-motion television, while offering greater program diversity, and potentially lower production and transmission costs on a per-program channel basis. However, needed additional ground reception equipment, and the problem of frozen noise make detailed cost and technical studies necessary before any final conclusions on the cost benefits of still-picture television may be made.

The most immediate limiting factor is that to display still pictures on conventional television receivers, means must be provided to regenerate each transmitted still picture thirty times a second. At present, this "speed buffering" can be accomplished by the use of storage tubes for black and white pictures, or by magnetic video disc units for black and white or color. Video tape recorders available today do not have the capability to step through a sequence of frames one by one without losing sync, cutting into the middle of a frame, or losing picture quality. This capability is available in

electronic video recording (EVR), but EVR films must be recorded in elaborate processing centers, from which the film cartridges are physically distributed (see Section 4.6.2.2).

2.4.1 Video Buffering

Television is a real-time medium in its basic design philosophy, and has its greatest impact when so used. For many years after its commercial development, the only practical storage system for TV programs was kinescoping, in which a motion picture camera is focussed on a TV monitor. The reverse is done to show films on television: a projector is linked to a television camera in a so-called "film chain". In 1956, Ampex developed and marketed the first videotape recorder. This employed erasable magnetic tape, and has become the preferred mode for storing television programs for delayed broadcast. However, because a great deal of desirable program material exists in film form, and because 16-mm motion picture cameras are preferred for field use because they are much more portable than commercial TV equipment, film has certainly not been eliminated.

Videotape recorders are usually operated on line; that is, every frame of a television signal is recorded, regardless of whether there has been any change in the picture. Some low-cost helical scan VTR's are available today which have a time-lapse recording feature, and some have limited slow-motion capability. However, slow motion is accomplished by slowing down the tape while maintaining the same head rotation, which gives a rather jumpy and noisy picture.

In recent years, a number of systems have been developed for "instant replay" of television signals ( 84, 85 ). These devices

usually embody a magnetic disc which can record a sequence of television fields around its circumference. Any single field can be displayed indefinitely by keeping a reproducing head above the track it has been recorded on. A frame--two interlaced fields--is displayed by using switching between two tracks and heads, or by simply repeating a single field with an appropriate time delay. A scene composed of several hundred fields can be reproduced at regular or slow motion speeds by changing head location relative to the spinning disc, which rotates at a constant speed of 60 rps, so that one revolution corresponds to one TV field (85).

Although magnetic video disc systems for black-and-white are available for as little as from $2000 to $3000 from such firms as Newell Industries (86) and Colorado Video, Inc. (87), systems capable of broadcast-quality color, have prices ranging from $50,000 (Data Memory, Inc.) to more than $100,000 (Ampex Corporation) per unit. Thus, price levels, and the price gap between noncommercial and broadcast-quality video disc recorders are somewhat similar to those of videotape recorders.

Of most interest in the context of this report is that a magnetic disc system can be used to record a series of still pictures which have been sent via conventional television techniques. They can be played back as individually selected stills or as a sequence of stills, with another disc acting as a video buffer. AV Electronics, Inc. has proposed such an arrangement for random-access video information storage and retrieval in their Apollo Information Retrieval System (88). This is an advance on dial-access information retrieval systems (DAIRS) technology,

which uses a small general-purpose digital computer as a process controller in place of the telephone crossbar switchgear usually employed.

Since the retrieval requirements of each organization vary a great deal, all Apollo systems are custom-made. However, a minimal video disc subsystem would cost $120,000 and up for hardware. It would include a 600-frame master disc with 16 buffer channels and video switch ($80,000), a 23-head buffer disc with a maximum 6 second retrieval capability, and a camera, switching, and cables for conversion of conventional picture sources to video signals.

Pictures recorded on the master disc are given digital addresses so that they can be randomly accessed by the processor (CPU). It takes 20 milliseconds to load a video frame onto the master disc; it can be located in a maximum of 2 seconds and transferred to a buffer head on the buffer disc in 30 seconds. Because all frames are individually addressed, they may be added to or deleted from the master disc at will without disturbing any other frames. Frames are copied onto the buffer disc only during the period of use. With 32 fixed heads, up to 32 different frames can be sent over local transmission facilities (e.g. coaxial cable) simultaneously.

If audio is required with the frames, Apollo uses remotely controlled reel-to-reel or cassette magnetic tapes, which have cue signals. These signals are routed through the CPU which starts a video update cycle.

Because typical filmstrip programs use about 40 frames, each video master disc unit can store up to 15 such programs. If users require more programs to be available on-line, it may be necessary to use

several master disc files. In the future, it may be possible to employ device specialization, whereby a single record-only device--perhaps a form of videotape recorder--captures the signals from the satellite. Then, the information could be transferred to a battery of playback-only devices for local distribution. If magnetic disc units can be brought down in cost to a few hundred dollars, they can be incorporated into individual television receivers. This would be useful for those schools which are not connected by cable or microwave to any center, and must receive programs by direct broadcast.

Still-picture television also may be possible by using low-cost non-magnetic video disc or cassette systems, as described in Section 4.6. However, programs in this form must be physically distributed. Still other possible systems include the use of storage tubes and signal conversion devices, as mentioned in Section 2.4.2.

Video technology has the potential to provide the means to display diverse media on ordinary television sets. Complementing television programs with other services can widen the choice of instructional material available to educators, and cater to more specialized interests than the economics of full-motion television allows.

Recapitulating Section 2.3.1, the advantages of the still-picture medium may be thought of as follows: The selling price of a 35-mm sound filmstrip print is only about $8, or 3% of the price of a $250 16-mm sound motion picture print of equivalent duration (see Table 5). The major portion of this cost difference is caused by the amount of film required: 4 feet versus 800 feet. Film uses 38 times more material than filmstrip, even allowing for the latter's 5.3 times larger frame

size (see Table 3). However, the portion of these savings which can be realized by still-picture television remains to be determined.

Another advantage is that less bandwidth is needed to transmit the still-picture television equivalent of a motion picture; however, this savings is difficult to quantify (see Section 2.4.2).

Balanced against these advantages are the additional equipment which will be required to utilize still-picture programs, which adds to the cost and complexity of the communication system. A detailed investigation of the necessary additional equipment and its cost is recommended to establish the viability of still-picture television as an alternative and supplemental service to satellite-based full-motion television.

2.4.2 Audio Requirements

As has been described, the number of programs broadcast in satellite-relayed television may be enhanced by a large factor, if motion is not required. However, to retain audio-visual capability, each TV frame should be accompanied by voice, music, and other sound information.

In analog form, only about 10KHz is required to transmit high-quality speech, as compared with 4.2 MHz for video. Thus, there would seem to be little to be concerned with in terms of bandwidth necessary for the sound transmission. However, if we are transmitting a sequence of <u>still</u> pictures to be used in a manner similar to the sound-filmstrip, the 30 pictures sent may be viewed over a duration as long as 10 minutes. These 30 pictures can be transmitted in just one second over the 6-MHz bandwidth of television, but ten minutes of sustained sound would have to be sent with them. For English, it takes from a third to a half second

to speak a word, in oral reading and conversation, respectively. Therefore, in normal television, from 10 to 15 frames are sent for the utterance of every word. If it is desired to maintain a 50:50 ratio of audio to visual information transmission, 30 still pictures might be sent in one second, followed by the sound to accompany them in the next second. This would require an audio compression of 600:1 (10 minutes times 60 seconds in 1 second).

One technique available for time compression of this magnitude is digital encoding. Mathews gives an analysis of analog versus digital trade-offs in high-fidelity sound recording (89). He states that if one minute of sound is sampled at 30 KHz, it produces 1.8 million samples. Using conservative digital-magnetic-tape technology (2400 feet of 1/2"-wide 6-track tape, recorded at 800 bits per linear inch), and assuming that 12 bits are required to resolve the analog sound wave, 400 sound samples could be packed into an inch of tape. Assuming that 10% of the tape length would have to be sacrificed for recording gaps, the entire tape could then hold approximately 10 million samples, equivalent to 300 seconds or 5 minutes of sound. However, Mathews assumes that the tape is not continuously moving, but must be searched, and therefore started and stopped; record gaps are essential when this is done to allow for the inertia of the tape and mechanism. This would not be necessary in the application considered here.

Each 2400-foot tape costs about $50, and a tape write/read mechanism able to use it costs at least $2,000. On the other hand, the same length of 1/4" audiotape, used for analog recording, could hold over an hour's worth of top-quality sound for about $5 ( at a

speed of 7-1/2 inches per second), and could be reproduced at good fidelity on a $100 audiotape recorder. Thus, it appears that present analog recording is about ten times cheaper than digital in terms of material costs, and at least twenty times in hardware investment.

Mathews also states that digital tape can be moved at speeds of from 60 to 150 inches per second. When multiplied by 400 samples per inch, this is equivalent to data transfer rates of from 24 to 60 KHz. At the latter speed, five minutes of sound could be sent in 18 seconds, a time compression of more than 15:1--but this falls far short of the 600:1 goal previously stated.

If we restrict the analysis to speech capability, and without employing elaborate redundancy-reduction techniques, 35 kilobits/second, or 12 to 18 kilobits per word, are required to send speech. Thus, 10 minutes of sustained speech would require $35 \times 10^3 \times 60 \times 10 = 21$ megabits. If the over-all signal-to-noise ratio of our transmission system is 30 db (1000:1), then in theory 21 megabits could be transmitted in one second over a bandwidth of about 2 MHz. In terms of the 6-MHz video bandwidth, about 9 frames would be needed to store or transmit this digitally-coded speech signal.

However, it would be difficult to achieve half this rate in practical systems. Therefore, 20 frames might be required to hold 10 minutes worth of speech--and to transmit it in one second, almost the full video bandwidth would be required. But the cost of storing this speech digitally should be no more than one fourth of full-range sound; that is, a $50 tape should hold 20 minutes of AM-radio quality sound. The 20

minutes of sound could be sent in 18 seconds, a 65:1 time compression, but this is still five times below the goal of 1 second for 10 minutes of sound.

Recently, very high-speed audiotape handling equipment has been developed. Newell Industries has marketed a unique transport design which moves tape at speeds up to 960 inches per second (ips) (90). Thus, high-fidelity sound recorded at 15 ips on a Newell drive could be reproduced and sent out at 960 ips, which would be a 64:1 speed increase. Signals could be recorded at the other end of a satellite communications link on another Newell drive running at 960 ips, and played back for listening at the 15 ips speed. Thus, analog compression techniques seem more promising at the present time than digital techniques. However, the problems of audio speed buffering seem to be comparable to those of video speed buffering for still-picture television.

Sharma has compared three alternative schemes for still-picture television transmission in a forthcoming thesis: slow-scan; time-shared video with frequency-shared audio; and time-shared video with time-compressed audio (91). For the latter scheme, Sharma has calculated the theoretical number of subchannels possible under various combinations of frame rate and audio compression. These calculations represent the upper limit of practical systems, because they make no provision for guard bands, sync, and other control signals which must be provided for video transmission. Also, no provision is made for signal degradation caused by noise, which is always present in real transmission systems, and which may become much more noticeable when "frozen" in a still-picture.

Therefore, only the theoretical maximum number of still-picture television subchannels which may be sent over a standard television bandwidth are given in Figure 6. For example, 90 subchannels would be theoretically possible if the composite frame time is 4 seconds, and if 10-kHz audio is compressed 420 times and transmitted using double-sideband amplitude modulation. To double the number of subchannels to 180, the frame rate must be slowed to one every eleven seconds. Using more complex single-sideband (SSB) modulation, 5-kHz audio could be used for an audio compression of 840. This would enable 105 subchannels to be transmitted at one frame every four seconds; 225 subchannels at one frame every eleven seconds; and so forth.

Various means to accomplish time compression and expansion of audio signals are suggested by Sharma. One possibility is to use an electronic storage tube to store images composed of frequency-converted PAM-sampled audio. Such storage tubes are commercially available from such firms as Hughes Aircraft, International Telephone and Telegraph, Princeton Electronic Products, Rauland Corporation, and Tektronix, Inc. They range in price from about $500 (without electronics) to several thousand dollars (with electronics), depending upon such factors as resolution, picture size, rapidity of picture change, and whether or not scan conversion is required.

An impression of the capabilities of still-picture television transmission can be obtained by assuming that one composite frame is sent every four seconds, and that a television channel is available 24 hours a day for this transmission. Also, assume that 5-kHz SSB audio is used, so that an 840 compression factor is possible. Then, 24 x 60 x 15 frames/minute x 105 subchannels, or over 2 million

N = number of subchannels (each comprised of one still-video plus one compressed audio frame)

T = composite frame time for transmittal of N subchannels

$v_1, v_2, \ldots, v_N$ = still-video frames transmitted during T

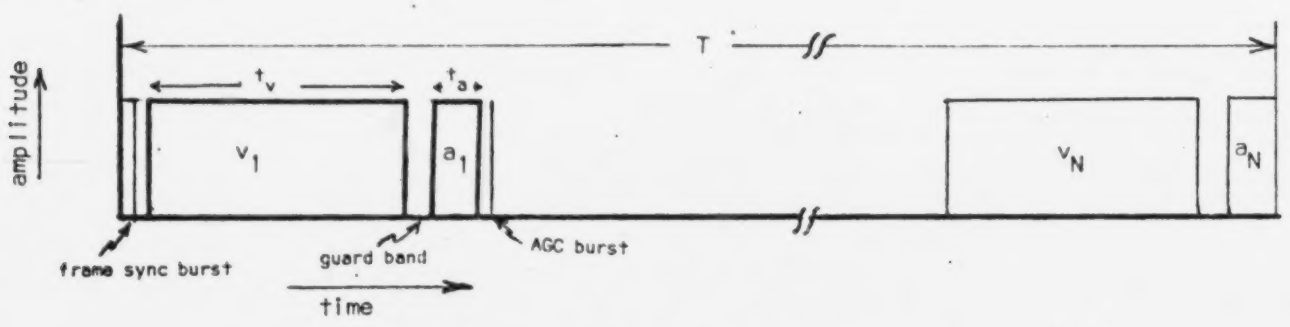
$a_1, a_2, \ldots, a_N$ = compressed-audio frames transmitted during T

$t_v$ = time to transmit one still-video frame

$t_a$ = time to transmit one compressed-audio frame

$C_a = \frac{T}{t_a}$ = audio compression factor (also equal to ratio of original video to audio signal bandwidths)

(all times in seconds; time guard bands, and AGC and frame sync bursts ignored)



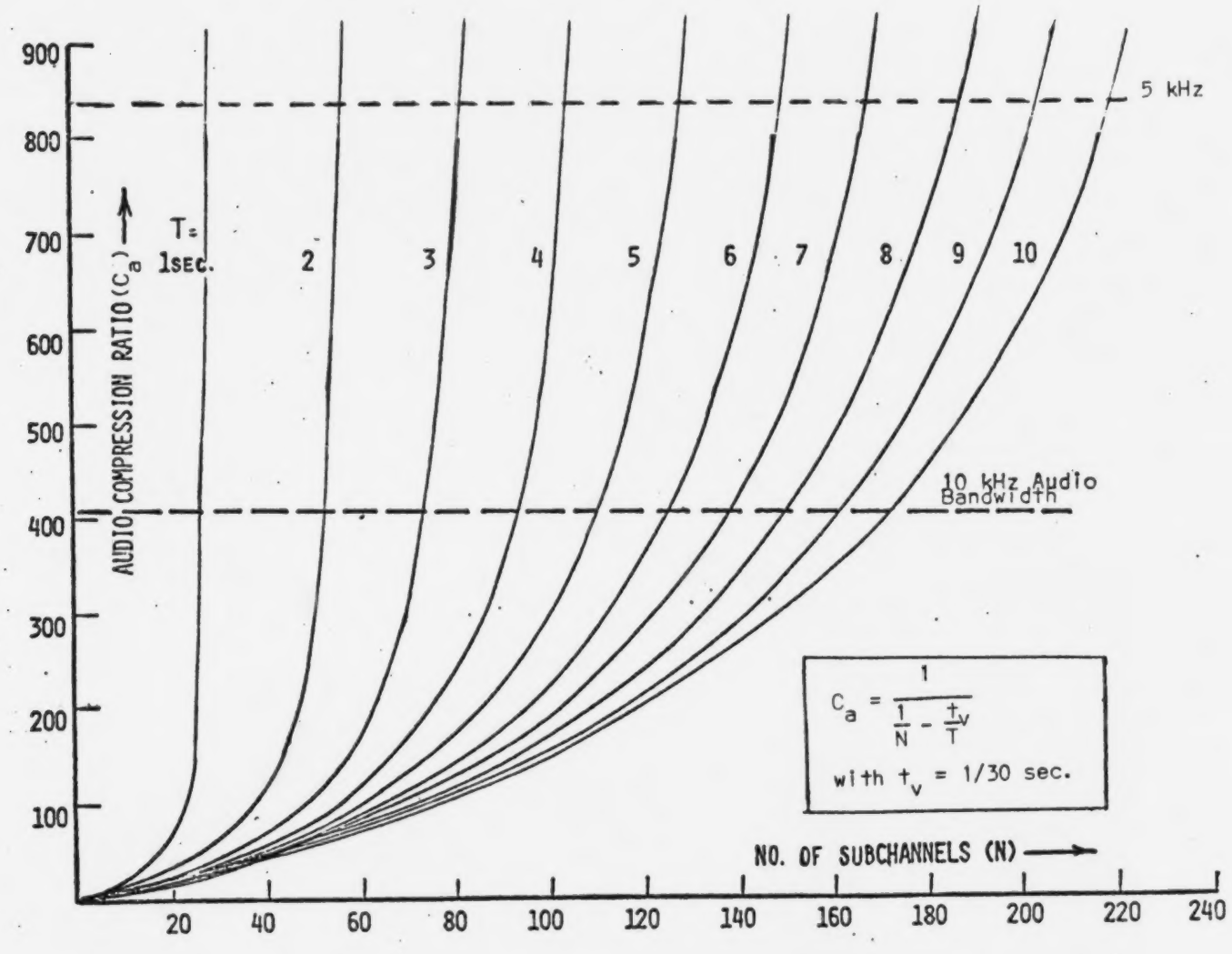




Figure 6: Time-Shared Video with Time-Compressed Audio
(after reference 91)

still-picture frames with accompanying compressed audio may be transmitted in 24 hours. If the average still-picture program is 50 frames long, up to 40,000 such programs could be broadcast every day. Typically, a 50-frame program would be viewed over about 8 minutes. Only 180 full-motion television programs of similar duration could be transmitted during a 24-hour period. Thus, still-picture television could theoretically provide more than 200 times as many programs over a given bandwidth as full-motion television, but how much of this advantage can be realized in practice remains to be determined.

2.4.3 Functional Motion

After still-picture television programs have been picked up by a ground station, it is possible to reintroduce some types of motion. Such techniques have been used in motion pictures since their invention. A motion-picture segment which has been made entirely from still pictures is called a filmograph. Animated motion pictures are also created from stills, but in such a way that they convey the illusion of motion just as though they had been made by a camera in the natural world. On the other hand, in a filmograph no attempt is made to give the illusion of real-world motion. That is, the "micromotions" of limbs, lips, and other muscular motions are not attempted, but only the "macromotions" of entire organisms and objects against a background.

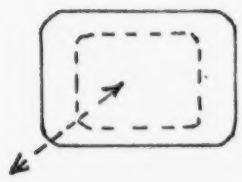
In still-picture television, not film but probably some form of magnetic storage is used at the receiving station. Therefore, the name filmograph would be inappropriate. The analogous still-picture television capability will be termed functional motion. As in filmography, rapidly changing noncyclic motion cannot be conveyed, but the

considerable variety of cyclic and linear motion possible may be very usefu' for instructional and motivational purposes.

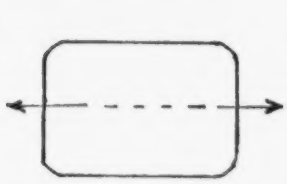
Functional motion has been used in commercial television for a number of notable art and history programs. Some of these were initially created as filmographs for direct projection, and some made especially for television viewing. Still pictures of paintings, drawings, and photographs have been given a feeling of motion by camera and/or lens movements relative to the objects being photographed or televised. If these techniques were not available, looking at a still picture for more than 10 or 15 seconds would become boring in many situations. However, creative cutting, panning, zooming, and other functional motions can help sustain interest in a single picture for periods up to a minute or more.

When functional motion sequences are analyzed, they are seen to be the result of combinations of a small set of physically or electronically controlled movements (see Figure 7 ). For example, zooming is obtained by rotating one portion of a zoom lens in relation to the rest of the lens; panning and rolling by relative motion between camera and object; fading by moving a diaphragm or shutter in film cameras, or electronically in television; and so forth. It would not be difficult to record signals for these motions in analog or digital form on a separate track, running in parallel with the picture and sound tracks on videotape.

Thus, programs telecast via satellite could have subchannels for video, audio, and control information. On the receiving end, this control information could be used to provide functional motion. As each still picture is retrieved from the store, the control information

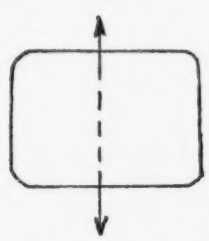


Zoom: scene appears progressively closer (camera "zoom in") or further away (camera "zoom out").



Pan: scene appears to move towards left (camera "right pan") or right (camera "left pan").

Crawl: words or artwork appears to move from right to left (usual) or left to right, superimposed on a background scene or blank screen.



Tilt: scene appears to move up (camera "tilt down") or down (camera "tilt up").

Roll: lines of type or artwork appear to move vertically from bottom to top (usual) or top to bottom, up or down, superimposed on a background scene or blank screen.

Fade
Dissolve } effects smooth transition between scenes.
Wipe

Blink: provides subjective animation effect by rapid alternation of positive and negative frames.

There are many other possible functional motion techniques, such as limited animation, progressive disclosure, polarity reversal, electronic matting, etc. Zettl describes many of these in detail (92).

Figure 7: Functional Motion Techniques

alters it electronically or electromechanically before it is sent out as a full-TV signal. This may be done with a flying-spot scanner, scan converter, or film chain linking a still-picture projector with a television camera.

Furthermore, a local user could add a functional motion track to an existing still-picture television program, or create a different track than the one received.

It is reasonable to ask why, if this technique can be so effective, it has not been more widely used with still pictures. Heretofore, there has been little reason to try to separate out motion, because commercial television has the full-motion capabilities of the medium available.

However, if it becomes important to conserve the electromagnetic spectrum, there is great advantage in separating out the motion function--as long as the limitations of this technique are fully appreciated. This is particularly true in satellite-distributed television, where bandwidth conservation is highly desirable, provided that ground stations are equipped to redistribute previously stored still-picture television programs, either by broadcasting or cable. In the latter case, a much larger number of local full-television channels may be accommodated than is available in the former--perhaps up to 40 CATV channels versus 10 VHF/UHF channels.

However, functional motion has its price. For example, conventional television resolution is not capable of providing sufficient information in a single frame to permit a "functional zoom." To see why this is so, consider a still-TV frame which is to be zoomed. At the beginning, its contents will fill the TV frame, but as the zoom proceeds, less and less of the original contents will fill the frame. Therefore,

if the original vertical resolution was 480 lines over the whole frame, at the end of a 3:1 zoom, only 160 of these lines will be present (and less than this horizontally). That is, if a zoom ratio of n:1 is employed, both vertical and horizontal resolution must be increased n times to maintain equivalent picture quality. Therefore, at the beginning of the zoom, the picture must contain $n^2$ times as many elements as at the end to provide the standard number of picture elements.

However, this does not preclude the use of functional motion in still-picture television, for in this case bandwidth may be traded for time. Thus, either $n^2$ times the bandwidth may be employed to maintain resolution, or $n^2$ times as long may be taken to transmit the information. For example, in a 3:1 zoom, $n^2 = 9$. The picture could be sent in 1/30 second over 54 MHz, or in 9/30 second (9 sequential TV frames) over 6 MHz, using conventional AM-VSB modulation.

Even this multiplication of frames may be unnecessary. It has been assumed that the eventual viewer will have a chance to observe each frame critically during the zoom progression. In reality, he will be unable to do this, and during the zoom the apparent resolution may change as it will, as long as the <u>beginning</u> and <u>ending</u> frames have full resolution. The same thing is true of panning and other transitional motions. Thus, instead of an $n^2$ factor, only a factor of 2n may be needed to provide a reasonably good functional motion capability.

The provision of a functional motion capability will add to the complexity and cost of any still-picture television system. Provision must be made to encode the motions onto a separate track, or multiplex them with other signals. At every receiving point, provision must be made to decode the signals, and automatically controlled physical or

electronic devices must be employed to translate these signals into action. No estimates of the cost of providing this capability will be attempted in this report. Therefore whether functional motion can be justified economically remains to be determined.

2.4.4 Distribution of Still-Picture Television Programs via Satellite

In distributing still-picture TV programs via satellite, no extensive modifications of existing or proposed transmitting stations should be required. That is, existing film chains can send still pictures at the standard TV frame rate of 30 frames per second, if they are converted to 16-mm form. Sound requires separate handling, but if spatially encoded, it could be placed on alternate frames, or in a contiguous series of frames after a series of still-pictures.

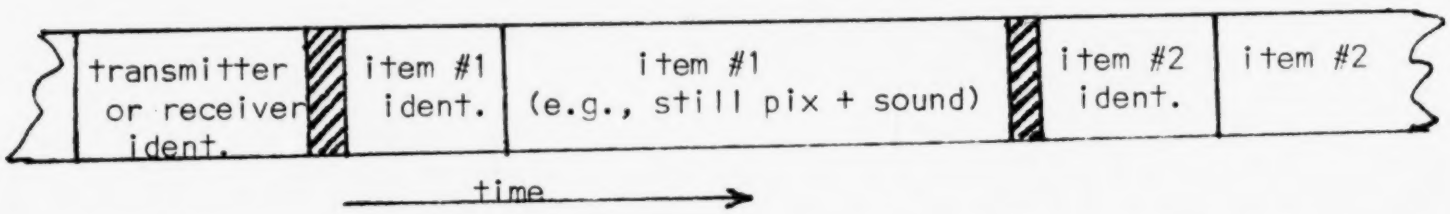
However, at each ground station, means must be provided to store the still-picture frames and convert them to standard TV signals by regenerating each still frame thirty times per second. Also, the encoded sound frames must be converted into normal FM audio.

However, given a ground program-buffering capability, there is no reason to follow conventional television distribution practice, in which all programs are sent simultaneously to all schools. Instead, program choice may be made highly selective. Appendix 2 provides an analysis of demand-access requirements for still-picture television programs.

Selectivity is possible using multiaccess communications satellite technology, such as the MESA technique proposed by Campbell (93). In MESA, each ground station would send out bursts of several kilobits. At the satellite, the received signals would be amplified by a simple broadband analog repeater. Each ground station burst would contain

an address signal to enable the addressee to pick out the correct bits from the total bit stream. One ground station would also transmit the required frame reference.

In MESA, both information and address are digital streams, but analog information could also be preceded by digital address codes. For example, each still-picture sequence to be transmitted from a ground station might have the following format:




Identification numbers might follow the practice of the International Standard Book Number (ISBN) scheme (94), which also provides information about the country of origin, and publisher or producer. Also other digital information could be provided concerning intended audience, number of frames in the program, length of viewing time, etc.

To pick out a particular still-picture program from the mass being broadcast by several sending stations, a special-purpose digital memory and control system could be provided at each receiving center. If programs were received at random--the most likely case--sufficient memory capacity would be required to handle the maximum daily requirements of that center's customers, or perhaps between 100 and 1,000 programs. If we assume complete identification takes 20 decimal digits per program, a memory of from 2,000 to 20,000 decimal digits would be required.

Items to be received on a particular day could be chosen from a printed catalog. Their identification numbers could be entered via keyboard or optical reader at each user location. If the receiving

equipment was left on standby twenty-four hours a day, whenever the desired program was broadcast the receiving station would be able to select it automatically by address matching.

If all programs were to be sent in ascending order by serial number, receiver memory requirements could be greatly lessened, perhaps to the extent that only 20 decimal digits per receiver would suffice. After one desired program had been received, the stored decimal identification would be erased and replaced by the next desired number in order, and so forth. However, if several different stations are sending simultaneously, there is no way to assure programs being received in ascending order at a particular ground station.

Using message store-and-forward techniques, problems of time-zone differences and local viewing convenience in conflict with broadcasting schedules would be eliminated. Programs could be made available from local centers whenever, and however many times a particular user wanted them. These techniques imply a hierarchy of access, beginning with the transmitting station, going through ground receiving and redistribution centers, and finally ending at the individual school, and perhaps the individual classroom or even student. In such a hierarchy, buffering equipment is essential.

However, if individual schools do not have buffering capability, complete flexibility of use is not possible. That is, only so many still-picture programs--now processed for local transmission over the full television bandwidth--can be sent simultaneously. With coaxial cable distribution, this limit is presently thirty to forty channels, and should suffice for all but the very largest school systems. Of

course, specialized receiving centers could be employed, each serving a different educational level, subject interest, or geographical area within a single metropolitan region.

Another problem arises if we want to determine which programs are being used. While it would be cheaper not to gather this information, it is likely to be required for legal and accountability reasons, such as copyright and royalty payments, and to insure that the system is operated on a financially sound basis. Also, it is useful to know the frequency of use of each program by each receiving location. Less popular programs might then be kept in less-accessible form.

A reliable way to gather this information--without requiring each receiving station to have sending capability--is to employ a recording mechanism on the ground that stores the identification numbers of all programs as they are received at each center. Tapes for these recorders could be packaged in convenient lengths to insure that they are returned within a reasonable period of time. For example, when one hundred identification numbers had been recorded on it, a tape might be filled. It could be mailed to a distribution center or central facility for billing, accounting, and statistical processing. Bills could be sent to the receiving stations, or funds debited from a yearly credit pre-established with each receiving point.

These schemes for obtaining individualized program access are based upon the assumption that no return capability will be provided from most receiving stations. However, this assumption may not be sustained in actual practice. Some centers may well have return capability, and accounting information then could be sent back to the

originating center or a specialized countrywide satellite-education headquarters processing center via satellite. Rapid two-way communication is only essential for such applications as teleconferencing and computer-assisted instruction. Some of the initial experiments with satellite-based educational networks may try out these applications.

# 3. COMPUTER-ASSISTED INSTRUCTION

## 3.1 INTRODUCTION

Few technological innovations in education have stirred as much expectation--and as much hostility--as computer-assisted instruction (CAI). Many of the ideas in the field of computer-assisted instruction have developed out of the earlier innovation of programmed instruction. Some advocates of programmed instruction maintained that the original linear program format devised by B. F. Skinner (95) was too rigid, and that to provide a significant degree of individualization, it would be necessary to provide alternate paths for learners (96).

However, the crude teaching machines which were all the rage in the initial wave of enthusiasm for programmed instruction during the early 60's were incapable of providing more than one or two levels of branching. Hence, branching enthusiasts turned their attention to the rapidly developing technology of digital computers, and CAI was born.

Computers can provide an unlimited degree of branching, as well as evaluate constructed student responses rapidly. However, the expense of developing truly flexible programs for a wide variety of students is extremely high, and present languages developed for CAI underutilize the vast logical capabilities of the computer. An exception to this is an extremely powerful general-purpose programming language--APL--developed by Iverson (97). Present implementations of APL are all interactive, and lend themselves naturally to CAI (98).

One of the most advanced CAI systems is PLATO at the University of Illinois. Alpert and Bitzer have described PLATO, CAI in general,

and the costs of CAI (99) ; Seidel, Kopstein, and Swallow (100) rebutted what they call "four technological misconceptions" in the Alpert and Bitzer paper.

Previously, Kopstein and Seidel (101,102) had done one of the first detailed economics studies of CAI, in which they maintained it could probably be made available at a cost as low as 11 cents per student hour, if the software and instructional programming costs could be shared by enough students. They also claimed that CAI could then become competitive with traditional teacher-assisted instruction (TAI), which exceeded 11 cents per student hour by 1959-60 even in rural areas.

Another economic study by Carter and Walker (103) compared the costs of installing and operating ITV and CAI in U.S. public schools. The daily costs of supplying a typical school system of 100,000 students with one hour each of ITV programming and CAI were estimated over a 150-day school year. ITV costs were from 5-1/2 to 30 cents per student hour, but CAI costs were estimated to be $1.80 per student hour for the simple drill-and-practice mode of instruction, and $4.80 per student hour for the more complex tutorial mode. The drill-and-practice mode is similar to the simplest type of programmed instruction--or even to flash cards. The tutorial mode involves a combination of programmed instruction and drill and practice, and may require terminals with more versatility than teletypes.

It is apparent that even well-conceived and intentioned economic studies of such new fields as CAI suffer similar problems of trade-off determination as will be seen in Section 4.7. If one is allowed to pick his assumptions, the cost evaluation easily may unduly favor one of the alternatives. A better way to do these studies would be to define

objectives as precisely as possible, and then find what technologies, or better mixes of technologies and people, might best serve these objectives. Then, if hard costs are available, the competing system which can do the job for the least cost can be ascertained with a fair degree of reliability. This sounds simple, but in almost any real situation, the number of unknowns--particularly when dealing with a new technology--is very large, and even the knowns may have a considerable range of variation.

## 3.2 COMPUTER-CONTROLLED INSTRUCTIONAL TELEVISION

One of the most interesting recent developments in CAI is the MITRE Corporation's TICCET (Time-Shared Interactive Computer-Controlled Educational Television) proposal. TICCET was originally conceived as a completely communications-oriented system, but evolved over a couple of years into a system whose only communication links are cables within a single school.

Originally, TICCET involved a massive $10 million central computer, which was to be accessed from 10,000 interactive terminals in a hundred different schools. Nuthmann (104) estimated that the one-time cost of such a system would be about 25 million dollars, with recurring software costs of a million dollars a year, and annual operating and maintenance costs of 2 million (see Tables 6 and 7).

Of particular interest in the context of this report was his statement that: "if the apparent continuous motion of television is forfeited a large number of television sets may receive different still-pictures over a single television channel". The system was to have handled four distinctly different types of information:

Table 6 : TICCET Design Parameters and Costs

| | Educational Computer Utility (original) Proposal (see ref. 104) one system to serve 100 schools | | In-School CAI/CMI Com single-scho |
|---|---|---|---|
| **Hardware** | | | |
| Terminals | 1 to 1.5 students/terminal | | 5 students/terminal/day |
| no. of terminals | 10,000 | | |
| terminal use | 6 to 12 hours, 250 days/year | | 5 hours |
| average student input time | 0.1 sec. (1 to 30 chars.) | | |
| average interframe interval | 10 sec. | | 10 sec. |
| terminal servicing rate | 1000/sec. | | |
| cost of terminals[3] @ $1000 each | | $10 million | $300 each |
| Computer, 800-ns cycle time | | | DDP-516, 960-ns cycle |
| core: 380,000 60-bit registers | $29 \times 10^6$ bits | | core: 64,000 16-bit words |
| disc: 10 to 20 each $5 \times 10^7$ to $10^8$ chars. | 4 to $8 \times 10^9$ bits | | disc: 4 type 273 disc pac each $18.4 \times 10^6$ cha |
| display generator: 2 72-channel disc units @ $60,000 | | | display generator: |
| cost | | $10 million | |
| Communications | 33 full TV channels on coax. cable & microwave; each channel time-shared by 300 terminals | | coax. cables within each |
| transmitter cost | $0.4 million | | |
| cable & microwave | $1.8 million | | |
| cost | | $ 2.2 million | |
| Facilities cost | | $ 2 million | Multiplexers, etc. |
| Total hardware costs | | $24.2 million | |
| Annual operating costs | | $ 2.4 million | |
| **Software costs** | | | |
| initial system development | | $ 1 million | initial curriculum develo |
| annual development | | $ 1 million | annual curriculum develop |
| Students served, 100 to 150/school | 10,000 to 15,000 | | |
| Total cost/student terminal-hour | | 12 to 37¢ | {intensive use, 2000 hr/ {normal use, 1000 hr/yr |

Table 6 : TICCET Design Parameters and Costs

| Proposal (see ref. 104) | | In-School CAI/CMI Computer Proposal (see ref. 105) | | | | |
|---|---|---|---|---|---|---|
| ools | | single-school system | | System in one school (unit quan.) | Systems in 100 schools (linear scale-down) | Systems in 1000 schools (proposal basis) |
| /terminal | | 5 students/terminal/day | | 128 | | |
| 0 days/year chars.) | | 5 hours | | | | |
| | | 10 sec. | | 2 to 3/sec. | | |
| | $10 million | $300 each | | $50,000 (including cables) | $2.5 million | $25 million |
| | | DDP-516, 960-ns cycle | 1970 | $120,000 | $12 million | $120 million |
| | | | (est.) 1974 | 70,000 | 7 million | 70 million |
| | | core: 64,000 16-bit words | | $10^6$ bits | $10^8$ bits | $10^9$ bits |
| | | disc: 4 type 273 disc packs each $18.4 \times 10^6$ chars. | | $6 \times 10^8$ bits | $6 \times 10^{10}$ bits | $6 \times 10^{11}$ bits |
| | | display generator: | 1970 | $120,000 | $8 million | $80 million |
| | $10 million | | (est.) 1974 | 65,000 | 4 million | 40 million |
| % microwave; minals | | coax. cables within each school (no transmitters or microwave) | | | | |
| | $ 2.2 million | | | | | |
| | $ 2 million | Multiplexers, etc. | 1970 | $70,000 | $3.5 million | $35 million |
| | | | (est.) 1974 | 30,000 | 2 million | 20 million |
| | $24.2 million | | | | | |
| | $ 2.4 million | | | $39,000 | $3.9 million | $39 million |
| | $ 1 million | initial curriculum development | | $2,000 | $200,000 | $2 million |
| | $ 1 million | annual curriculum development | | $2,000 | $200,000 | $2 million |
| | | | | 500 (1 hour/day) | 50,000 | 500,000 |
| | 12 to 37¢ | {intensive use, 2000 hr/yr | | 60¢ | | 20 to 35¢ |
| | | {normal use, 1000 hr/yr | | $1.20 | | 40 to 73¢ |

Table 7 : TICCET Frame Requirements

Educational Computer Utility (original) Proposal

one system to serve 100 schools*

| no.of frames | frame type | bit requirement | bit rate |
|---|---|---|---|
| 900 | alphanum. | 10 Kbits each | 9 Mbits/sec |
| 100 | still TV & voice | 200 Kbits each | 20 Mbits/sec |
| 1000 | terminal address | 14 bits each | 14 Kbits/sec |
| Total, system output channel | | | 30 Mbits/sec |

*response contingent addressing; assume 90% of frames contain only alphanum. info.; frame change rate, one per second.

In-School CAI/CMI Computer Proposal

single-school system+

| no. of different frames | frame type | frame capacity | total data requirement |
|---|---|---|---|
| 80,000 | text | 350 bytes | 28 Mbytes or 224 Mbits |
| 30,000 | pictures[1] | 1000 bytes | 30 Mbytes or 240 Mbits |
| 1,500 | voice | 4000 bytes | 6 Mbytes or 48 Mbits |
| 2,000 | user records | 1000 bytes | 2 Mbytes or 16 Mbits |
| 100 | algorithmic | 2000 bytes | 0.2 Mbytes or 1.6Mbits |
| Total all frames | | | 66.2 Mbytes or 530 Mbits |

+priority queue addressing; picture frames are ½ TV screen width each; one-third of text frames have pictures; voice frames are 1-second duration each.

alphanumeric, graphic, voice, and algorithmic. An average 10-second interframe interval was specified for all terminals.

Recently, the TICCET project has been reorganized. Although still devoted to CAI, the TICCET system has been redesigned to be small enough to be located at each school, and thus be independent of communication lines. In this new proposal, there would be 100 TV-based terminals in each 500-student school, for a present unit cost of $480,000, which is estimated to drop to $265,000 by 1974 (105).

Furthermore, TICCET's new manager, Kenneth Stettin, maintains that if a thousand TICCET systems could be marketed, the present cost would drop to $260,000 per unit, and to $155,000 by 1974. Maintenance would be about $25,000 a year; software and curriculum development $2,000 a year (pro rated on a per-school basis); installation and engineering (amortized over 8 years) $10,000 a year; and floor space and consumables, $4,000 per year.

One way to compare the costs of the old and new TICCET proposals is to simply multiply the present figure of $260,000 per system (in quantities of 1000) by 100 (the number of terminals in a school). If this is done, it is seen that the total capital cost of 26 million dollars is just about what the cost would have been for the original system, which included costs of broadcasting, microwave, and cable for the equivalent of 33 full-television channels. However, the approximately 5 million dollars saved by eliminating these communications links may (but this is difficult to ascertain) be traded off for a more responsive or more versatile system as far as students and teachers are concerned. Some of the desirable features of the new TICCET are that:

1. the system should accommodate enough simultaneous terminals to serve an entire elementary school;
2. the system should provide most sensory and response features desired by educators (alphanumerics, still pictures, voice, and silent keyboard response);
3. the data base should contain all data sufficient to teach basic reading and basic math on-line.
4. the entire system should be based on existing hardware;
5. the first equipment put into the field should be low enough in cost (perhaps $300 per terminal) so that participating school systems could afford to continue use on their own after the experimental period.

TICCET has been funded by MITRE's independent R&D Program, "Computer-Controlled Education TV Pilot System" (project 9710). They are now actively seeking outside support. However, as Nelson notes:

> "MITRE is developing TICCET at a time when most firms are retrenching their CAI efforts in disillusionment after overoptimistic predictions of past years and illusory profits. How the TICCET system could eventually be marketed is as yet unclear. MITRE itself is prohibited by its charter from being in the hardware business." (106)

Another potential problem area of the proposed system concerns its use of digitized voice vocabulary. In their proposal, Stettin, Morton, and Mayer state that:

> "The number of bits per second required to synthesize each second's duration of voice is surprisingly large...6,000 samples per second. Each sample [must be] six bits to provide the degree of accuracy required [or] 36,000 bits per second to reproduce telephone quality voice.... To avoid using enormous amounts of the data base for the voice messages accompanying many of the instructional frames, a system is used in which each of 1,500 one-second voice segments is digitized and recorded only once in the disc drives." (105, p. 19)

Therefore, they conclude that only "30 percent of the 128 terminals are using the voice feature at any given moment." The 1,500 phrases to be stored are probably a reasonable amount for the two subjects to be included--reading and math for kindergarten through the sixth grade. However, the mechanical quality voice synthesis, coupled with the other robotic features of the system, could cause trouble with parents and teachers, if not students. Furthermore, systems are now available which can synthesize a more natural sounding voice directly from a stored repertory of basic speech phonemes, such as VOX I, a product of the Culler-Harrison Company (107). VOX I could also be used to alter the rate of speech presented to the student, without decreasing the intelligibility or natural quality of the synthesized voice.

However, from the standpoint of cost both the proposed MITRE system and VOX I are not likely to be competitive with some of the newer adaptations of analog audio technology. Recent developments in tape cassette technology have made it possible to provide up to four independent tracks on a tape cassette, so that limited branching capabilities are made available. Also, several hundred voice segments could be made available via 8-track stereo cartridge technology, as has been done for dial-access medical information at the universities of Wisconsin (108,109) and Missouri (110).

Also, digital magnetic disc hardware, which is the major storage element for all four forms of information--alphanumeric, graphic, voice, and algorithmic--is extremely expensive. The original TICCET proposal employed Data Disc 72-channel systems, at a total cost of almost $60,000. The high cost of Data Disc equipment is in large part due to the necessity to design the discs to record and retrieve very

high-density digital information; hence the heads must be in intimate contact with the recording surface. An additional disadvantage is that the discs used in this unit are quite expensive, and must be physically changed in every school to change or update the curriculum.

In conclusion, there is considerable doubt whether an all-digital system is the correct choice at the present state of development, or whether analog technology should not be retained for the bulk of the information stored, with digital technology employed only for control, response, and logging purposes. With the proper mix of these technologies, an even more cost-effective CAI system could be made available.

Furthermore, until effective, low-cost two-way communication with satellites is available to a large number of schools, their main CAI role is likely to be in the distribution of CAI programs. However, this is a highly useful function, as CAI in its present state of development requires more revision than conventional instructional materials. Also, given the distributional power of a television broadcast satellite, CAI program writers may be encouraged to modify their overly verbal techniques in favor of more audiovisual content.

A major stumbling block of most CAI efforts in the past has been in the limitations of the terminal, usually a teletypewriter linked to a remote computer via the telephone network. Although undoubtedly one of the lowest cost interactive devices available ($600 to $800 each), teletypewriters are very noisy and slow (10 characters per second).

However, many manufacturers are now attempting to surmount the defects of the teletype as a remote terminal, while keeping costs within its range. One of the most promising terminals for CAI use is Picturephone (see Section 4,5.1).

## 3.3 INTERACTIVE GRAPHIC DISPLAYS

Particular attention has been given to cathode-ray tube (CRT) displays, which produce no hard copy, but enable their users to get access to the most up-to-date version of computer-stored information, at a convenient location, and at a pace and amount consonant with their needs and preferences. A comprehensive review of interactive display terminals is given in a three-part series by Brick and Chase (111-113).

Most low-cost interactive display terminals on the market are capable of handling only numerals and letters--"alphamerics". Such terminals usually are employed as replacements for Teletype machines, and consist of a keyboard coupled to a CRT, with local electronics for character generation and control. Present unit prices for CRT alphameric terminals are about $2000.

CRTs are bulky, heavy, and require high-voltage power supplies. Therefore, numerous attempts have been made to replace them with opto-electronic devices (114, 115). Table 8 compares recent non-CRT display technologies (116). Promising solid-state techniques are electroluminescent panels, light-emitting diodes (LED), and ferro-electric ceramics (117). Other devices are gas-filled, such as the plasma display panel (118), or liquid-crystals (119). However, until CRTs can be displaced as the preferred technology in television, there is little likelihood of such devices taking over in other than alphameric applications, where TV provides the mass market base essential for keeping costs down (120). Furthermore, display devices which have graphics capability allow for a much more natural man-machine interface, and the vast array of CRTs available provide the display designer with great choice and flexibility.

Table 8: Comparison of Recent Electronic Display Devices
(adapted from Reference 116)

| Display Technology | Advantages | Disadvantages |
|---|---|---|
| Solid-State | | |
| Fiber optics | High contrast ratio<br>Low voltage requirements | Complex logic<br>Catastrophic failure |
| Powdered Phosphor | No parallax problems<br>Fast display speed<br>Thin package<br>Low cost<br>No catastrophic failure | Requires 250V, 1 KHz power supply<br>Severe temperature and humidity limits<br>Poor contrast<br>Complex logic<br>> 1000 hr life typical |
| Light-emitting diodes (LED) | No parallax problems<br>Fast display speed<br>Thin package size<br>Low voltage requirements<br>Indefinite life<br>No catastrophic failure | High cost<br>Complex logic<br>Segmental size limits<br>Negative temperature coefficient<br>Severe halation |
| Light-emitting thin films (LEF) | Adjustable brightness<br>High contrast ratio<br>No parallax problems<br>Fast display speed<br>Thin package size<br>High temperature and humidity specifications<br>Completely dead front<br>Low cost: $1.50/digit<br>100,000 hour life<br>No catastrophic failure | Requires 150V, 1 KHz power supply<br>Complex logic |
| Liquid | | |
| Liquid crystals | Color versatility<br>Thin package<br>No catastrophic failure | Severe temperature limits<br>Dependent on ambient light for brightness<br>Slow display speed |
| Gaseous | | |
| Cold Cathode<br>example: Burroughs "Nixie" | Simple logic<br>Widely used<br>Production economies | Significant halation<br>Poor contrast<br>Severe parallax problems<br>Radio frequency interference<br>Catastrophic failure |
| Gas discharge<br>examples: plasma display, Burroughs "Self-Scan" | No parallax problems<br>No catastrophic failure | High cost<br>Complex logic<br>260V power requirement<br>Slow display speed<br>Temperature and humidity limits<br>Narrow viewing angle |

Some terminal systems also provide for interaction through manipulative devices, in addition to the usual typewriter keyboard. Sutherland (121) gives a good review of the state-of-the-art of these devices.

Tektronix has interactive graphic units available for from $8000 to $9000. Optical joystick control is available for the T4002 terminal. Parallex-free crosshair cursor positions are continually monitored, so that the operator may use them to indicate locations to be acted upon by a remote computer (122).

Bendix has designed a joystick controlled interactive terminal specifically for use with an IBM 1130 computer, which has enabled them to provide plug-in hardware and a FORTRAN software package for only $5500. This system has plotter/CRT compatibility so that plotter programs can be displayed on demand, and vice versa (123).

Spatial Data Systems Datacolor systems use a black and white TV camera and video recorder or film scanner to generate a standard TV signal, whose gray shades are analyzed by a digital processor. Then, a different color is assigned to each of up to 10 categories of gray shades, and a color TV signal generated and displayed on a color monitor. These systems can be used for qualitative or quantitative analysis of aerial photos, x-rays, and other graphic intelligence without elaborate photographic processing (124).

Computer Image Corporation has developed Scanimate and Animac, in which special purpose computers are directly linked to sophisticated CRT displays to provide very versatile animation for film and TV production (125,126). Scanimate converts artwork into a moving image, which then is filmed or videotaped. Animac, a more advanced device, generates its own images internally, and each image can have up to thirty different

segments which can be manipulated with six degrees of freedom. Animac also can generate cartoons and move them on the screen in response to the muscular motions of a person wearing a harness. Thus, a cartoon character can be made to move its mouth in coordination with a speaker, to provide lip synchronization in any language. This extremely sophisticated device is probably the closest we have come to providing the simulated world envisioned by science-fiction writers. Also, it is claimed that these devices can save more than half the cost of manually produced animation; for example, one minute of animation can be produced for between $2500 and $3500.

There has been a see-saw battle between the advocates of simple terminals linked to sophisticated computers by communications lines, and sophisticated terminals which either "stand-alone" (Scanimate and Animac, for example), or only communicate with a remote system when their computational capabilities prove inadequate. The present trend is to build more capability into terminals, so as to free up the central computer to handle a greater number of terminals. However, it is quite possible that as more competition causes communications to drop in cost, the pendulum will swing back towards very low-cost simple terminals. Communications satellites and CATV utilization could certainly speed such a swing. The trade-offs between communications-oriented and stand-alone terminals should become more apparent as new computer-communications services become more widely available.

# 4. ELECTRONIC VERSUS PHYSICAL DISTRIBUTION OF EDUCATIONAL MATERIALS

## 4.1 INTRODUCTION

This chapter surveys emerging technologies for physical and electronic distribution of information. The emphasis throughout is upon selective dissemination, rather than the mass dissemination characteristic of broadcast services. It starts with an analysis of two historic rivals for individualized information interchange, postal and telephone services, and then discusses mass broadcast services and the potential of electronic distribution of educational materials by satellite.

Then, facsimile, a system for the electronic transmission of information already in graphic form, is discussed. This is followed by a description of new microimaging systems which are expected to reduce the cost of physical distribution of printed information.

The discussion then shifts to nonprint communication, as exemplified by the visual extension of the telephone system, Picturephone, and a potential rival, cable television. Then, new physical distribution media for audiovisual materials--cassette and disc storage of television programs--are described.

The chapter ends with an evaluation of these various forms of information dissemination, and their place in the future of education.

## 4.2 TECHNOLOGICAL DISPLACEMENT: COMMUNICATION VERSUS TRANSPORTATION

The extent to which telecommunications has displaced the physical transport and delivery of messages in our society is much greater than generally realized. When the United States first became a nation, no form of electronic communication was available, so that all communication

other than face-to-face contact among small groups of individuals entailed the writing and physical delivery of messages. However, once telephonic communications became established, the need for the physical transport of messages was subject to severe competition. Telegraphy is an intermediate case, which requires either physical delivery of the message to its intended recipients after electronic transmission, or uses the telephone system for this last phase.

Figures 8 -10 illustrate the history of postal service (127) and telephone common-carrier operations (128) over the last three decades in the United States. Figure 8 shows annual mail volume versus telephone calls originated. By the end of the 1930's, calls placed exceeded items mailed, and since then calls have been growing exponentially, while mail volume has grown linearly. In 1966, annual calls completed exceeded 140 billion, which was about twice the 1966 mail volume. Recently, telephone calls have grown at a compound rate of about 6% a year, while the number of telephones installed has been increasing at about 5% a year. This difference may be attributable--at least in part--to the ability of the telephone subscriber to have ever greater access to other subscribers without any increase in cost. Also, some of this traffic may have been gained at the expense of the Post Office.

Figure 10 shows annual revenue and expenditures for the U.S. Post Office and U.S. telephone common carriers. Operating revenues of the telephone carriers have increased exponentially over the three decades, but although carrier operating expenses and taxes have also grown exponentially, this rate of growth is considerably less. This is a particularly advantageous situation for the telephone common carriers, as it implies increasingly profitable business.

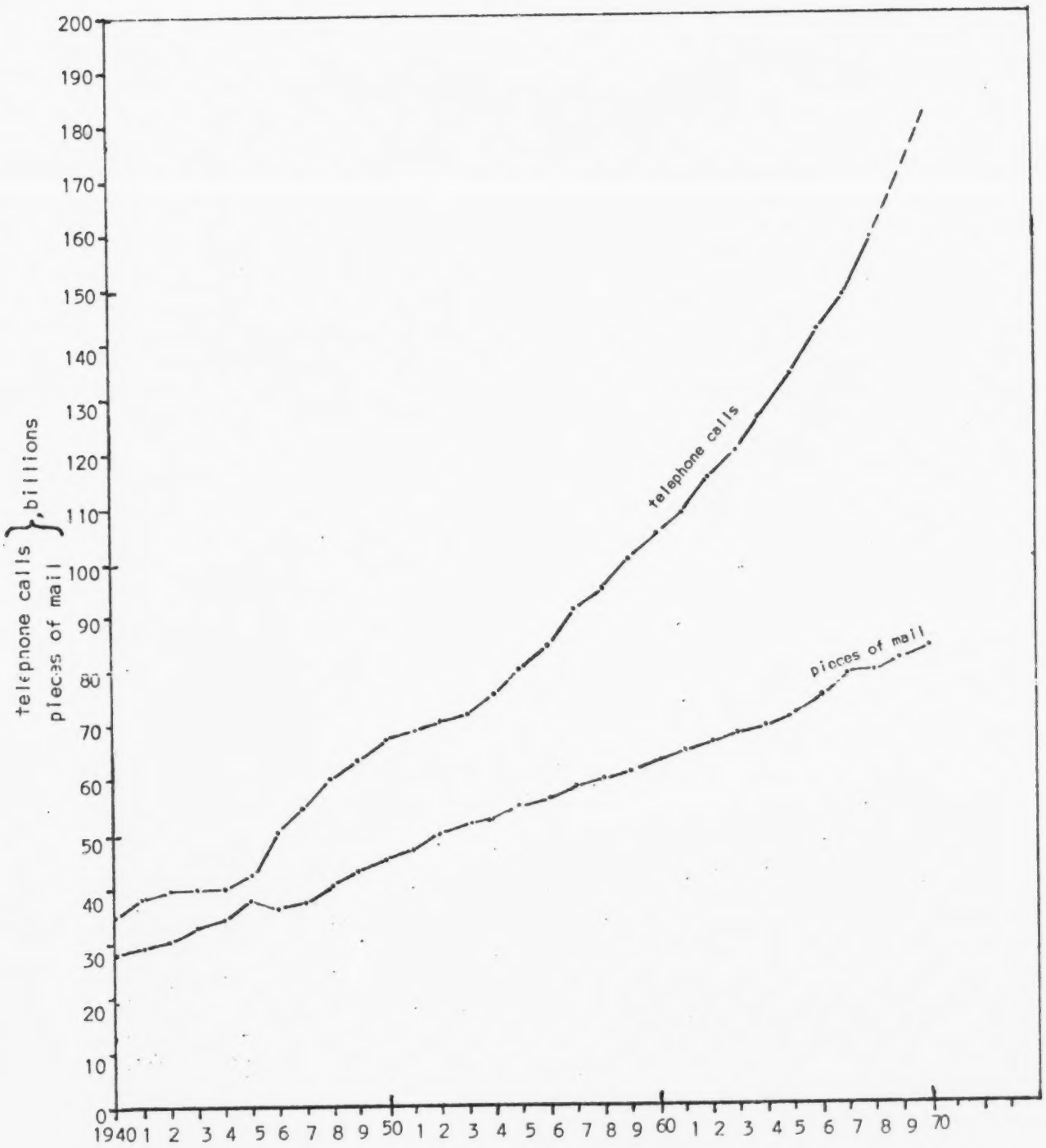



Figure 8 : Comparative Growth of Telephonic Communications and Mail, 1940 - 1970

Notes: Telephone data points are taken from reference (128), and postal service data points from reference (127). The two sets of data are not strictly comparable, because the former are on a calendar-year, and the latter on a fiscal-year basis; however, this does not affect the comparative trends shown. Telephone data include only telephone carriers who filed tariffs with the FCC in a particular year; 55 carriers filed in 1968. The number of calls includes both local and toll originating from company and service telephones; however, after 1950 only local calls which were actually completed are included. In the postal figures, mail volume or number of pieces handled refers to all classes of mail.

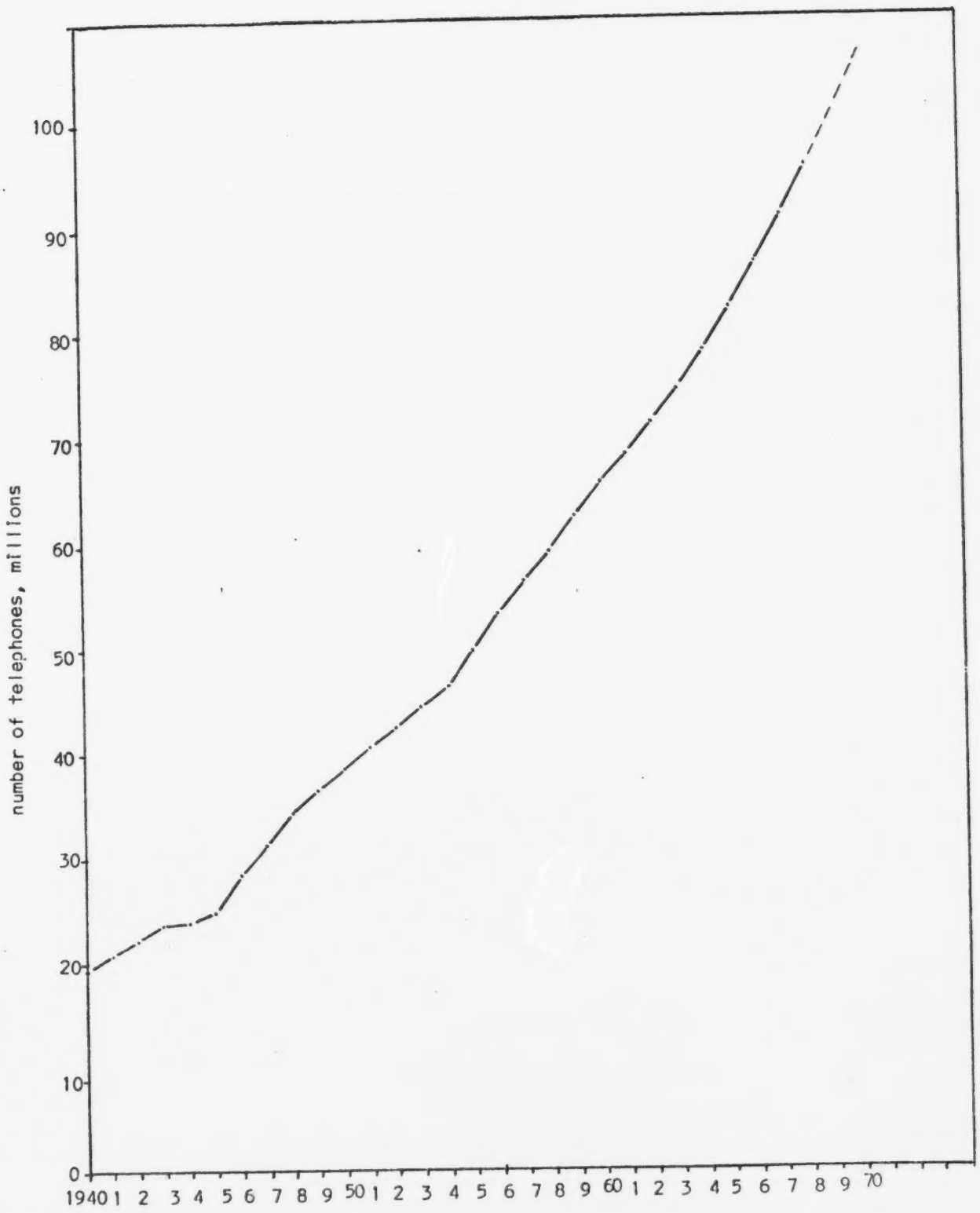



Figure 9: Growth of Telephone Sets, 1940 - 1970
(Data points taken from reference 128)

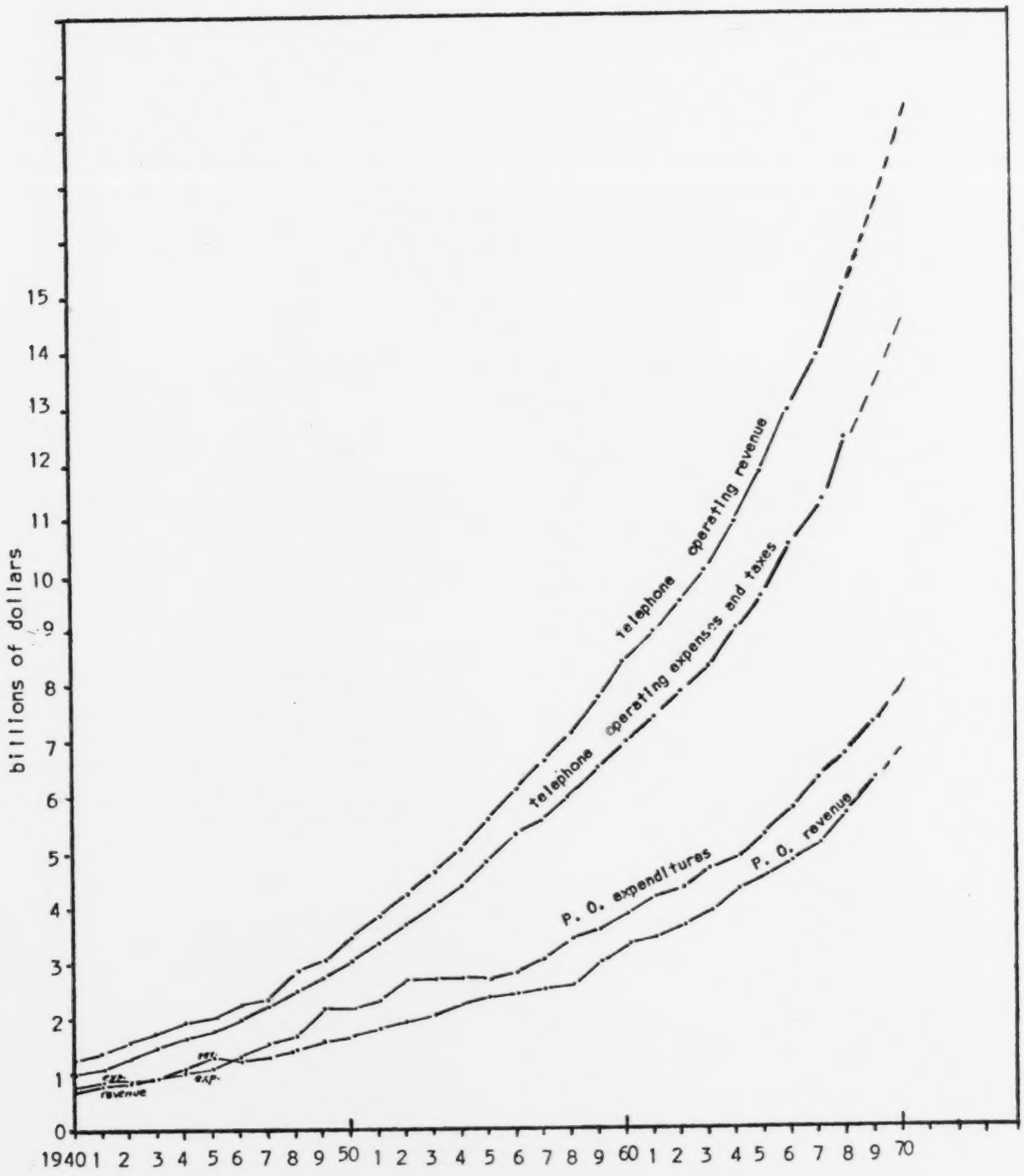



Figure 10: Comparative Revenues and Expenditures of U.S. Telephone Common Carriers and the U. S. Post Office, 1940 - 1970

**Notes:** Telephone data points are taken from reference (128), and postal service data points from reference (127). The two sets of data are not strictly comparable, because the former are on a calendar-year, and the latter on a fiscal-year basis; however, this does not affect the comparative trends shown. Telephone data include only telephone carriers who filed tariffs with the FCC in a particular year; 55 carriers filed in 1968.

4.2.1 Postal Services

During the sixties, while telephone calls were increasing at a compound annual rate of 6%, the growth of mail volume has averaged about 3% a year. And whereas Post Office revenues and expenditures were in balance during the early forties, an increasing deficit has been its plight ever since. This has led the Federal government to re-examine historical subsidies for certain types of mail (129), culminating in the Postal Reorganization Act of 1970, which will turn the Post Office into a quasi-public corporation in mid-1971. The newly designated United States Postal Service will attempt to reduce the deficit, and eventually each service will have to pay its own way (130).

The Postal Service will be run by an 11-man Board of Governors, who will have autonomy in making day-by-day decisions. Fundamental policy will still be determined by Congress, but ratemaking will be the prerogative of a 5-member Postal Rate Commission. A Postal Advisory Council, with four members representing major mail users, four postal labor unions, and three the public at large will consult with the Governors.

Despite these changes, there is little likelihood of vastly improved postal service as long as messages of widely varying form and content must be physically delivered to a recipient. A comparison with the telephone system shows what the postal corporation is up against; the only profitable class of mail is first class.* Letter mail will cost 8¢ with the inauguration of the Postal Service, and they will offer a priority mail service with a sliding cost scale. Priority mail will

*Parts of other classes also have been profitable in the past, such as second-class controlled-circulation publications, third-class single-piece and bulk-rate mail, fourth-class zone-rated and catalog mail, and various government and special services (130).

get the most expeditious handling, with local same-day delivery a major target. However, a local telephone call still only costs 10¢, and long-distance rates at off-peak times are less than $1 to any part of the country. This may be a much better bargain for the customer, because the contents of an entire letter, and furthermore an immediate response to it, can be communicated in a couple of minutes. Only if a hard-copy of these messages is desired is physical delivery necessary, and within certain legal constraints, the same goal may be achieved with low-cost cassette tape recorders attached to customer telephones.

Certainly, however, the Postal Service has a unique function to perform where physical delivery of vast quantities of messages to individuals over great distances is necessary. Until satellites for telephonic communications become available, sending a letter should continue to be an order of magnitude cheaper than making a phone call over long distances. However, communication satellite costs are essentially independent of distance, and common-carrier toll tariffs will have to reflect this. Then even long-distance mailing may become of questionable value for many classes of material.

However, there is no inherent reason why the Postal Service cannot take advantage of electronic transmission for mail service. Electronic messages which are to be received as hard copies are essentially of two types--those which are composed by means of keyboarding operations; and those which already exist in written form and/or may contain graphic information. The former can be transmitted by telegraphy techniques, and the latter by facsimile. Both of these telecommunication systems have not enjoyed much success recently, but they are expected to take on new vitality under new technological and marketing conditions (131).

For example, electronic mail could be a service which works in conjunction with cable television. Gross (132) claims that an electronic "transaction-mail" system can be provided at 10 cents per letter, if a telegraphy type of service is used; that is, store-and-forward transmission of alphanumeric messages. Transaction mail, which includes bills, purchase orders, proposals and the like, comprises 40% of the total volume of mail, so that a large portion of the physical delivery demands on the Postal Service could be alleviated by an electronic transaction mail system.

It is important to note that the new Postal Service intends to put all services on a pay-their-own-way basis, but non-profit rates cannot be raised above their directly attributable costs over a 10-year period--unless Congress fails to appropriate an annual subsidy for them (133). In any case, there is a strong possibility that advantageous rates for educational materials will be eliminated eventually, and it is not too soon for educators to look for alternatives to physical distribution. This chapter is intended to provide some knowledge of these alternatives.

4.2.2 Telephone Services

At the present time, a sharp demarcation exists between those electronic communication systems which are intended for individualized use, and those designed for mass dissemination. The former is exemplified by the vast switched telephone network. This is used largely for person-to-person communication, and to some degree for person-to-machine communication using keyboard input and voice-answerback (134). However, special arrangements must be made for simultaneous communication among

more than two telephone sets. Such arrangements are necessary for teleconferencing (135-138) and telelecture (139-146) hook-ups, and until recently, have required the services of a conference operator. However, an organization called Telesessions is now offering small groups of people the ability to hold a teleconference using equipment they have had developed (147). As will be seen in Section 4.5.1, the diversity of services available over the switched telephone network will be greatly increased with the advent of Bell's videotelephone service: PICTUREPHONE® (148).

4.2.3 Broadcast Services

At the other extreme from these specialized services are broadcast radio and television, designed to reach the greatest number of people at the lowest cost. The only way broadcasters usually measure their audience's interest and participation is by using rating services, which attach monitoring devices to a small but supposedly representative sample of homes. Such devices generally show only when the set is turned on, and what channel it is tuned to. This is an extremely superficial way to measure complex human behavior (149). As described in Section 4.5.2, the rapid development of cable television (CATV) is expected to increase both the number of channels available in a community, and the interaction possibilities of television. This should change television from a purely mass medium to one with considerable individualization (150).

This bridging of the communications gap between individualized and mass service is expected to accelerate with the advent of communication satellites. Messages can be relayed, stored, and individually addressed

for local, regional, national, and international communication. The word audience will become inappropriate for such services, as it literally means "listener", and implies a passive role, rather than active participation.

Initial communication satellite applications are expected to follow established patterns of person-to-person voice communications and mass-audience broadcasting. Also, it should not be surprising that these uses will be supplemental to and under the control of existing communications organizations.

However, many educational needs which are not being adequately met by existing systems can be aided by communications facilities, such as:

1. Teacher training (136, 143, 144)
2. Interinstitutional communication (142, 151, 152)
3. Community-school communication (153)
4. People-to-people communication (137, 147, 154-156)

Many of these types of communication require two-way or even multiway hookups--but they seldom require complete symmetry of facilities. And they don't fit either present extreme of person-to-person telephony or mass broadcasting. The communication satellite should not be regarded as threatening existing telephone and broadcast systems, but as providing a new capability whose place in the communications mix is yet to be determined.

4.2.4 Electronic Materials Distribution

Another type of service which is particularly important for education is the provision of supplementary materials for instruction and reference. Most common are textbooks, reference books, workbooks,

and tests--print materials, in library parlance; and various forms of audio-visual aids--nonprint materials.

Most of these materials are obtainable in only one way at present--by physically transporting a copy and reproducing it locally, or by transporting multiple copies to various locations. These materials are usually purchased directly by school systems or cooperative regional educational processing centers. Much paperwork and a long lead time is required before the materials can be utilized in the classroom--sometimes as long as a school term. Even more serious is the rapid obsolescence of many of these materials. On the other hand, if materials are borrowed or rented, we are also faced with long lead times, and--because the materials must be returned--even more elaborate record-keeping.

For example, motion pictures are usually borrowed rather than bought, because each half-hour 16-mm color sound print costs several hundred dollars to acquire. In 1964, the New York State Education Department reported that films were out of circulation for two weeks for each actual "use"--and that 58% of teachers responding to a survey could not depend on the film arriving in time to fit in with their lesson plans (157). Certainly, this type of service can discourage even the most avid film user.

However, with the advent of educational television networks and videotape recorders, it has become technically feasible to send an "electronic copy" to those locations desiring it, instead of mailing or trucking it. Furthermore, although ETV networks usually air their programs on a scheduled basis, they have the potential to provide materials on a request basis--"on demand".

An extensive proposal emphasizing electronic film distribution was developed by the North Circle Production Center Project in St. Louis County. This concept was dubbed "television is a truck" by Paul Andereck, Director of Audiovisual Education of the Cooperating School Districts of the St. Louis Suburban Area (158-160). Educational materials--particularly films and videotapes--would be transmitted via microwave or cable from an audiovisual center on high ground in the middle of St. Louis County to a number of "production circles". Each production circle would store received material on videotape recorders, and hold it until requested by school districts or teachers within the "circle". At that time, or during the preceding night, they would be retransmitted to videotape recorders in each school. However, as of this time, the North Circle Project has not been implemented.

A less versatile type of electronic distribution is in use in a number of schools and colleges, called "dial-access information retrieval systems" (DAIRS) (161-164). DAIRS make a number of audio, and in some cases video (165), channels available simultaneously. Students and teachers use a simple telephone dial (or TOUCH-TONE$^{R}$ buttons) to obtain programs of their choice which are transmitted by private wire to individual headsets, or via the switched telephone network to regular telephone sets. Properly set up, DAIRS can provide effective, economical audio information service (166). However, most DAIRS have not been used extensively for demand access to a large body of materials. Instead, they make a limited selection of curriculum-related audio programs available on-demand for a limited period.

To extend demand access, elaborate information retrieval systems (88), and a larger number of audio-video channels need to be provided.

Viable solutions to the information retrieval problem will entail much greater cooperation with large materials depositories, and electronic computers may be required to handle the involved searching, switching, and bookkeeping required (167).

For the electronic distribution of printed materials, some form of facsimile transmission may be used. In the past, facsimile has been found to be too costly as a replacement for physical transport and delivery, as shown in a number of telefacsimile experiments to replace interlibrary loan service (168-172). However, as communication satellites become available, one of the most costly elements in present facsimile transmission--common carrier lines--is replaced by broadband communication links, and facsimile may become an attractive alternative to physical distribution for many types of printed educational materials.

## 4.3 FACSIMILE SYSTEMS

Facsimile provides a permanent recording or "facsimile" of an original on paper or a reproducible medium (e.g., printing master) at a remote location. Facsimile transmission techniques have been available for over half a century (173), and they stem from the same inventive fount as television (174). Both facsimile and television involve dissecting a two-dimensional spatial image, usually by scanning, into a one-dimensional time-varying signal for transmission. At the receiving end, the image is reconstituted through an inverse process. Television is usually used in transmitting images of the real world, whereas facsimile is usually used to transmit printed documents.

Where rapid delivery of a newly written verbal message is required, telegraph and telephone are preferred; it is only when it comes to

rapidly transmitting graphic materials that facsimile offers a unique service. Thus, the biggest present user groups of facsimile are newspapers which obtain photographs over phone lines via "Wirephoto" service, and such government organizations as the Defense Department and the Weather Bureau (175).

Table 9 summarizes a wide variety of facsimile-type systems (176) Scanning of the original document or image may be accomplished optically, by means of a cathode-ray tube (flying-spot scanner or image dissector), by electron-beam, or even by laser beam (177). At receiving points, the image may be reconstituted on paper or film by pressure, heat, electrostatic,electroylytic, or photographic means; or possibly on storage cathode-ray tubes. Transmission may be over a telephone line, if one page in six minutes is sufficiently rapid, or in a fraction of a second using wideband communications systems.

One of the puzzles of communications technology is why facsimile has never fulfilled one of its brightest promises, the "newspaper in the home". Finch Telecommunications, Inc. and Radio Inventions, Inc. marketed home facsimile sets using the FM broadcasting band in the late 1940's (see Figure 11) (173). In 1967, RCA announced--but decided not to market--a "Homefax" system which "hitchhiked" on regular TV programs by making use of unused lines in the vertical blanking interval (178).

However, the viability of this concept is apparent in Toshiba's newly marketed home facsimile receiver, using a nearly identical trade name--Home Fax. This receiver will deliver a 13 x 18-inch newspaper page of 200-line-per-inch resolution in 5-2/3 minutes over a 240-MHz wide channel situated just below UHF channel 14. Toshiba

Table 9 : Comparison of Scanned-Image Transmission Sy

| APPLICATION/MARKET | Types of originals which may be transmitted | Transmitter sensing/scanning system | Resolution, scan lines per inch | Scan rate, lines/min. (unless otherwise noted) | Transmission Speed Using: 1 voice grade line (sw. phone network)[5] | Broadband facilities | Receiver scanning/p system |
|---|---|---|---|---|---|---|---|
| PRESENT TECHNOLOGIES | | | | | | | |
| Office Communications | | | | | | | |
| Alden DocuFAX 11 | ≤24"wide, any length | flatbed | 96[1] | 120<br>240 | 6.8 min/page<br>3.4 min/page | | |
| Graphic Sciences, Dex I | | drum | 88 | | | | |
| Graphic Transmissions, Bandcom | | flatbed | 96 | 450 rpm | 2.3 min/page | | |
| Int'l Scanatron with Pacfax modem | | flatbed | 96 | 180<br>360 | 7 min/page | | |
| Litcom, Messagefax | | drum | 100 | 180<br>300 | 6 min/page<br>3 min/page | | |
| Muirhead, Mufax | | drum | | | | | |
| Shinotron, QIX 503 | | | 89 | 142<br>216 | 6.7 min/page<br>4.5 min/page | | |
| Steward-Warner, Datafax | | | 96 | 120<br>900 | 4.5 min/page<br>1 min/page | | |
| Teleautograph | | | 100<br>85 | 180<br>300 | 6 min/page<br>3 min/page | | |
| Xerox Telecopier III[2] | ≤8½ x 14" | drum | 90 | | 6 min/page | | pressure s |
| Xerox 400 Telecopier | ≤8½ x 11" | drum | 60<br>90 | | 4 min/page<br>6 min/page | | scriber |
| Xerox LDX | ≤9½" wide, any length | FSS | 135<br>190 | | | 0.57 min/page[3]<br>1.1 min/page | CRT/seleni |
| Periodicals | | | | | | | |
| Muirhead | 10 x 10" photo | | 100<br>150 | 60 rpm<br>120 rpm | | | |
| Litcom, Photofax | 8 x 8" photo | | 200 | 150 | 6 min/print | | |
| Litcom, Colorfax | Polaroid color prints | | | | | 5-2/3 min/page[7] | |
| Toshiba Home Fax AT-3 | 13" wide x 18" long newspaper | | 200 | | | | |
| Wirephoto | photo | drum | 600 to 1500 | | | 20 sec to 2 min/photo[4] | miniature t |
| Weather | | | | | | | |
| Alden AlpurFAX | ≤60" wide, any length | flatbed | 96 | 120<br>240 | 4.4 min/pace<br>2.2 min/page | | |
| APT | | | 75 | | 4 line/sec<br>3-1/3 min/picture | | |
| Television | | | | | | | |
| Standard | anything which may be imaged by a lens | image dissector; 525 lines in 1/30 sec FSS; vidicon | | | | | |
| Ampex Videofile | 8½x14" pages; fan-fold paper; 16- or 35-mm microfilm | TV camera | 1280 TV lines in | 30 sec. to 1/15 sec. | | 2 pages/min. to 15 pages/sec[6] | |
| FUTURE TECHNOLOGIES | | | | | | | |
| Electron-beam recording Kodak (also, CBS, 3M) | | FSS | 6-μ spot size | 100 M bits/sec | | | electron b |
| Laser scan recording (CBS Labs, Image Systems, Inc.) | | modulated laser beam | >2000; 20K elem/line | 100 scans/sec | | | laser bea |
| Holography | | multibeam laser | $10^8$-$10^9$ bits | | | | laser |

[1] 166 lpi avail by using manual switch

[2] Magnavox Magnafax unit is the original (same as Telecopier I)

[3] Series 8000, 48 KHz

[4] Series 8000, 48 KHz, or five times faster over Series 5700, 240 KHz

[5] In this column all pages are assumed to be 8½ x 11"

[6] 2 pages/minute, Series 8000 ; to 15 pages/second on 7.6 MHz cable

[7] 240 KHz bandwidth over 469.1 MHz UHF carrier

Table 9 : Comparison of Scanned-Image Transmission Systems

| er canning | Resolution, scan lines per inch | Scan rate, lines/min. (unless otherwise noted) | Transmission Speed Using: 1 voice grade line (sw. phone network)[5] | Broadband facilities | Receiver scanning/printing system | Receiving material | Selling/monthly leasing Price (transceiver unless otherwise noted) |
|---|---|---|---|---|---|---|---|
| | 96[1] | 120<br>240 | 6.8 min/page<br>3.4 min/page | | | | $9950 or $150/mo |
| | 88 | | | | | electrosensitive paper | $2900 or $75/mo |
| | 96 | 450 rpm | 2.3 min/page | | | | — |
| | 96 | 180<br>360 | 7 min/page | | | electrolytic paper | $100/mo.[9] |
| | 100 | 180<br>300 | 6 min/page<br>3 min/page | | | | $75/mo<br>$3500 Xmtr/3200 rcvr |
| | 89 | 142<br>216 | 6.7 min/page<br>4.5 min/page | | | | $1759 or $65/mo |
| | 96 | 120<br>900 | 4.5 min/page<br>1 min/page | | | | $99 to 109/mo<br>$3000 or 124/mo xmtr<br>$2800 or 119/mo rcvr |
| | 100<br>85 | 180<br>300 | 6 min/page<br>3 min/page | | | | |
| | 90 | | 6 min/page | | pressure stylus | carbon paper set | $2500 or $55/mo |
| | 60 | | 4 min/page | | scriber | whitecoated black paper | $50/mo |
| | 90 | | 6 min/page | | | | $650/mo Xmtr[10] |
| | 135<br>190 | | | 0.57 min/page[3]<br>1.1 min/page | CRT/selenium drum | ordinary paper[8] or offset master rolls (automatic cutter: | —<br>550/mo. rcvr |
| | 100<br>150 | 60 rpm<br>120 rpm | | | | | $4350 or 195/mo Xmtr<br>7900 or 350/mo rcvr |
| | 200 | | | | | | $85/mo Xmtr; $180/mo rcvr |
| | | 150 | 6 min/print | | | color filmpacks | $550/pair/mo |
| | 200 | | | 5-2/3 min/page[7] | | | — |
| | 600 to 1500 | | | 20 sec to 2 min/photo[4] | miniature lamp | photographic paper | — |
| | 96 | 120<br>240 | 4.4 min/page<br>2.2 min/page | | | electrolytic paper | $9550 or $975/mo |
| | 75 | | 4 line/sec<br>3-1/3 min/picture | | | | |
| issector; 525 lines in 1/30 sec | | | | | | | |
| dicon | | | | | | cathode-ray tube | camera $200 up<br>monitor $200 up |
| era | 1280 TV lines in | 30 sec. to 1/15 sec. | | 2 pages/min. to 15 pages/sec[6] | | cathode-ray tube | up to sev. $million per system |
| | 6-μ spot size | 100 M bits/sec | | | electron beam | microfilm | |
| ted laser | >2000; 20K elem/line | 100 scans/sec | | | laser beam | photographic film | |
| eam laser | $10^8$-$10^9$ bits | | | | laser | photographic film | |

[5] In this column all pages are assumed to be 8½ x 11"

[6] 2 pages/minute, Series 8000 to 15 pages/second on 7.6 MHz cable

[7] 240 KHz bandwidth over 469.1 MHz UHF carrier

[8] output 8½" wide, any length

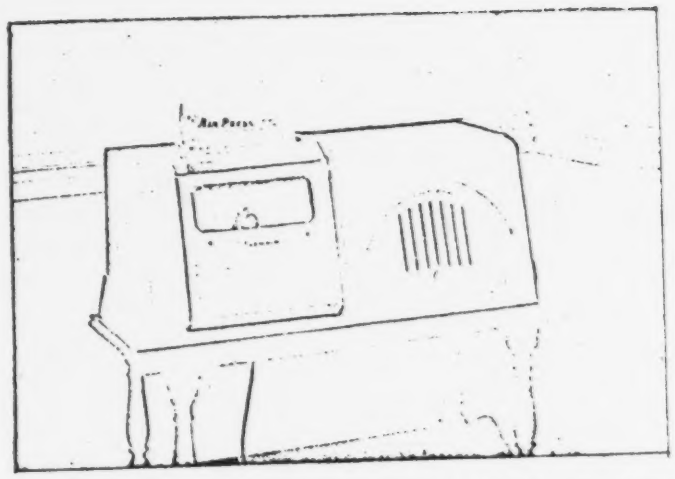
[9] Pacfax bandwidth compressi modem $75/mo.

[10] automatic document feeder (optional, $40/mo.)

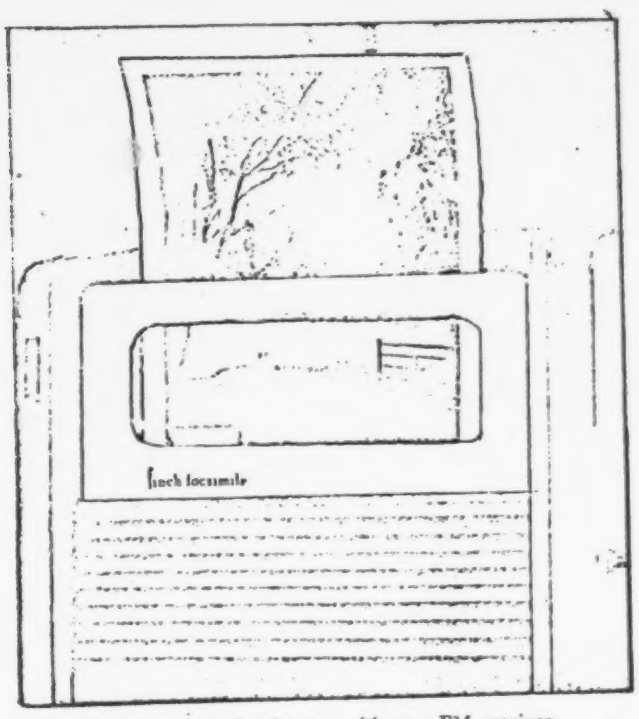
lecopier I)

rles 5700, 240 KHz

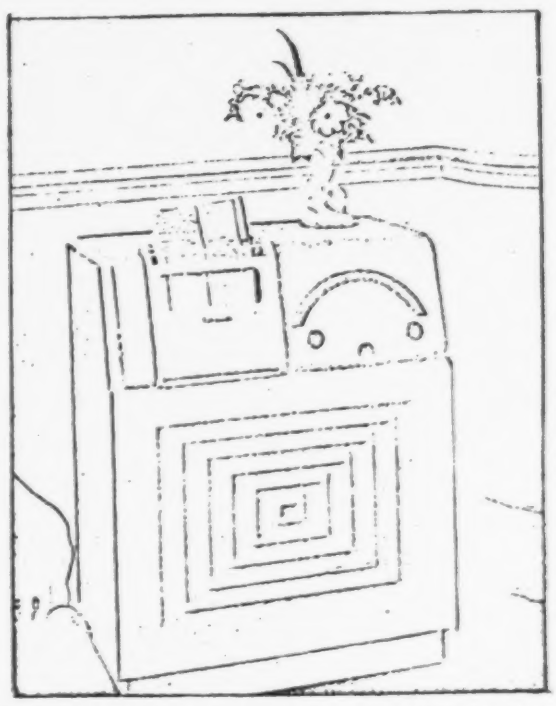
Late-model radio set-facsimile recorder combination for broadcast reception. *(Courtesy of Radio Inventions, Inc.)*



Facsimile-radio table model combination. An AM-FM radio set combined in one cabinet with a broadcast facsimile recorder. *(Courtesy of Finch Telecommunications, Inc.)*




Small broadcast recorder for use with any FM receiver. *(Courtesy of Finch Telecommunications, Inc.)*



Finch combination AM-FM radio and facsimile recorder for home reception of both sound and facsimile broadcasts. *(Courtesy of Finch Telecommunications, Inc.)*

The FCC set standards for 8 1/2 pp. at 3 1/2 linear inches per minute -- much higher than that found in other facsimile communications--when FM was employed.

Figure 11: Facsimile for the Home in the 1940's (after reference 173, pp. 32 ff.)

intends to sell these receivers for as little as $300 if the market allows mass production techniques to be used (179).

Such a development could have great utility in education, particularly if a duplicating master can be produced directly in the receiver, as described in Section 4.3.2. Facsimile transmitters would only be needed in relatively few information-originating centers, which would prepare various materials for transmission. Besides the "newspaper of the air" potential, a 13 x 18-inch area at a 200-line-per-inch resolution could be used for a variety of other printed materials, such as maps, charts, and multipage documents. Four book-sized pages could be transmitted together and folded into a booklet for distribution, without collating, cutting, or stapling, as shown in Figure 12.

Undoubtedly, the lack of a mass market has held back the growth of facsimile, as well as the lack of a beneficial time-cost trade-off to most potential customers. Unless there is great urgency to deliver a hard-copy message, it is hard to compete with a physical delivery system, particularly with messages of article and book length.

4.3.1 Using Facsimile in Education

For educational use, printed materials may be divided into two categories: instructional materials and reference materials. Printed instructional materials overlap transparency/slide media to a certain extent, but provide a basically different educational experience. Such materials can be written upon with pen or pencil,

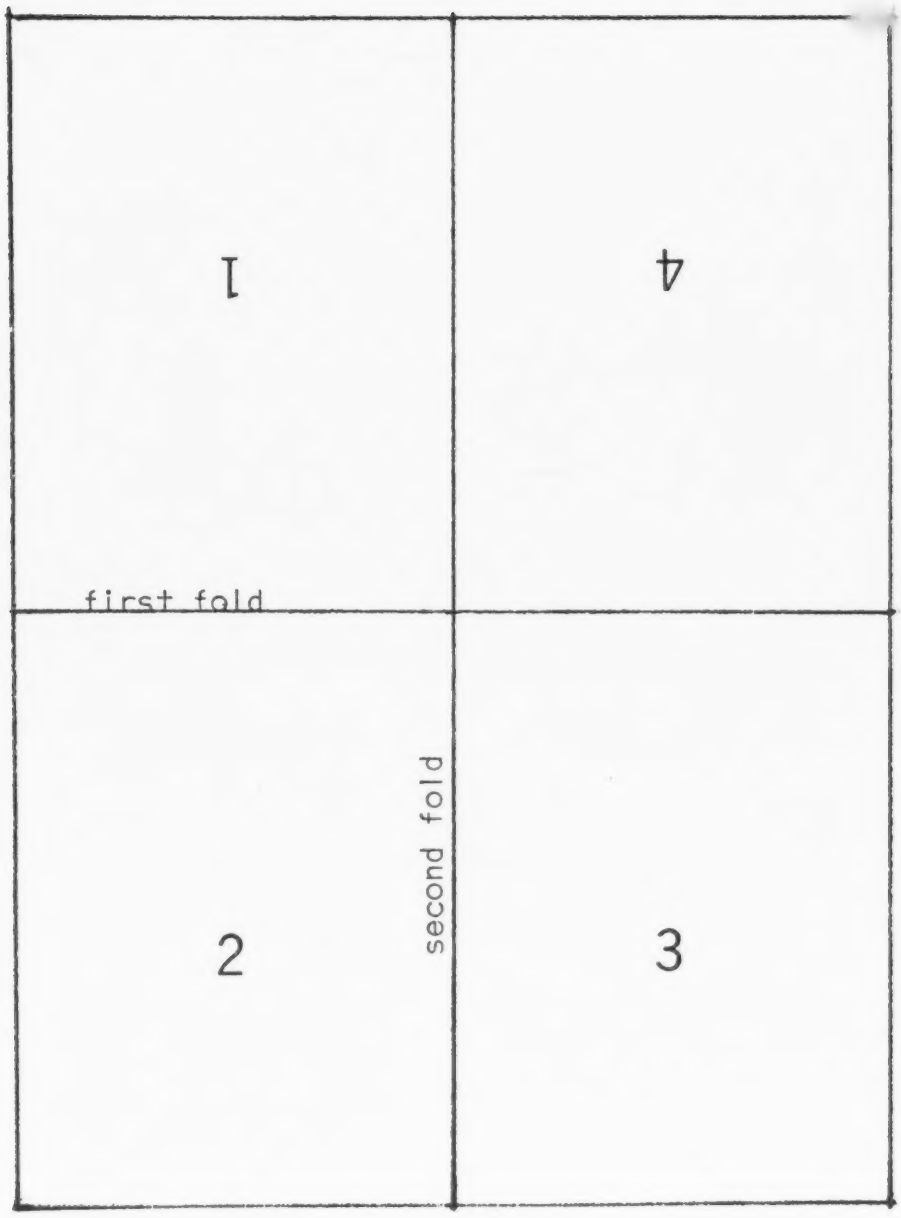



Figure 12: Imposition for Facsimile Booklet Transmission

and used as low-cost student interaction media, such as workbooks and tests.

On the other hand, reference materials, such as tables, graphs, charts, and lists, are supplementary to instruction, and may be made available to students in a form for occasional, but convenient referral. Reference material has great potential for individualized in-depth exploration of a subject, and is the area which has drawn the greatest interest and activity from professional groups interested in mechanized information retrieval.

However, if printed educational materials are to be transmitted by facsimile, costs must come down. Currently, a public facsimile service, FAXMAIL, charges from $2.75 to $3.75 plus a 6-minute telephone charge to send one 9 x 14-inch page of information (180). Costs should come down as transmission speed is increased, and when lower cost terminal equipment becomes available.

Many companies are actively engaged in developing lower cost facsimile devices employing bandwidth compression to speed up image transmission from 2 to 5 times. Also, AT&T is now under competitive pressure from new common-carrier applicants, such as MCI (Microwave Communications, Inc.) (181), and Datran (Data Transmission Company, a subsidiary of University Computing Company) (182), to offer better tariffs for nonvoice services.

For educational materials distribution, transceivers are not necessary, and a one-way facsimile system should suffice. Communications satellites could provide broadcast facsimile services, and eventually educational materials centers could make available

materials in facsimile-compatible form for on-demand satellite transmission. Any school system or community center with equipment capable of receiving and processing these signals could regenerate a copy of items of interest, or make masters for running off their own copies. Two variants of one-way facsimile systems are particularly promising for this type of service: microfacsimile and facsimile-based duplicating.

4.3.2 Microfacsimile and Facsimile-Based Duplicating

At both sending and receiving ends, microfilm images have advantages over paper as a facsimile medium (183). A transparent medium provides a much better signal-to-noise ratio, and the smaller images can be scanned faster. Also, because microfilm is a continuous medium, it can be moved at much higher speeds than individual sheets of paper. In 1948, RCA experimentally transmitted a microfilmed book at 480 pages per minute over their Ultrafax system, using a bandwidth of from 3 to 5 MHz (184).

If equipment suitable for receiving and utilizing microimages were available in schools and community centers, a pure microimage system (185) would be an excellent choice for facsimile recording. However, the current stage of the microimage art does not lend itself to easy individual student use, which is particularly important for instructional materials, such as workbooks and test. This situation is changing rapidly, and microimaging is expected to play a much larger role in the future (see Section 4.4.2).

An alternative system of more immediate availability is to have sending centers store all materials in transparent microimage form, but

at receiving points employ a scanning mastermaker. Scanning stencil-cutters are made by duplicator concerns, such as Roneo and Gestetner. Original and stencil master are placed side-by-side on drums, whose scanning heads move in tandem to minimize synchronization problems (186). There is no inherent technical reason why scanning and recording functions cannot be separated physically, and the process adapted to long-distance communications. Roneo manufactured a few such units fifteen years ago in their home country, England; however, they cost nearly $12,000 each, and transmission required six telephone lines.

Once made, electronically produced stencils can be run on that most common of school reproduction equipment, the mimeograph machine. Alternatively, masters for ditto and multilith could be prepared, or in certain specialized cases, single copies made directly using electrostatic copier technology.

For instructional materials of a motivating kind, color duplication may be important, particularly in the lower grades. The Roneo organization is now marketing an electronic stencil cutter with a color head for $1575. It produces 3- or 4-color separation stencils for duplication on the Roneo 865 Stencil Printer, in which stencil-holding drums can be changed in 25 seconds.

4.3.3 Facsimile Design Goals

The state-of-the-art of commercial-grade facsimile transmission (96 lines per inch) over the switched telephone network is such that it takes as long as 6 minutes to transmit an 8-1/2 x 11-inch page. Using dedicated and conditioned telephone lines, this can be brought down to about 2 to 3 minutes, and to 1 minute with bandwidth compression. Digital

facsimile is also a possibility; its advantages and disadvantages have been analyzed by Wernikoff (187).

In satellite communications, there is no inherent reason to confine facsimile technology within telephone bandwidths. Therefore, a design goal for educational facsimile via satellite might be to transmit a typewritten page in one second at a user cost of 25 cents, which is about one-tenth of current costs. At the de-facto facsimile standard of 96 lines per inch, the bandwidth needed for such transmission capability would be only 3-1/2 MHz, which is comparable to low-quality television.

A microfilm-to-microfilm system with 100-line-per-mm resolution should be able to transmit one typewritten page in 1/3 of a second at a user cost of 5 cents. This would require the full television bandwidth of 6 MHz.

A critical difference between facsimile transmission of a micro-image document page, and a still picture for audiovisual use is resolution. In television systems, an over-all resolution greater than 1000 TV lines is necessary to transmit an 8-1/2 x 11-inch page which contains 8-point type, a size commonly used in magazine printing. The television raster contains only 500 lines, and the equivalent horizontal resolution is usually considerably less. Thus, the bandwidth required to transmit an entire document page at TV's 30-frame-per-second rate is at least 3 to 4 times as great as a television program requires. However, this may be compensated for by slowing down the transmission rate--if we could utilize the resulting higher-resolution signal at the receiving end.

Again, microfacsimile is an attractive recording possibility, because it could be made compatible with audiovisual requirements.

Thus, much of the equipment necessary to store and process images for still-picture television and for facsimile would not have to be duplicated.

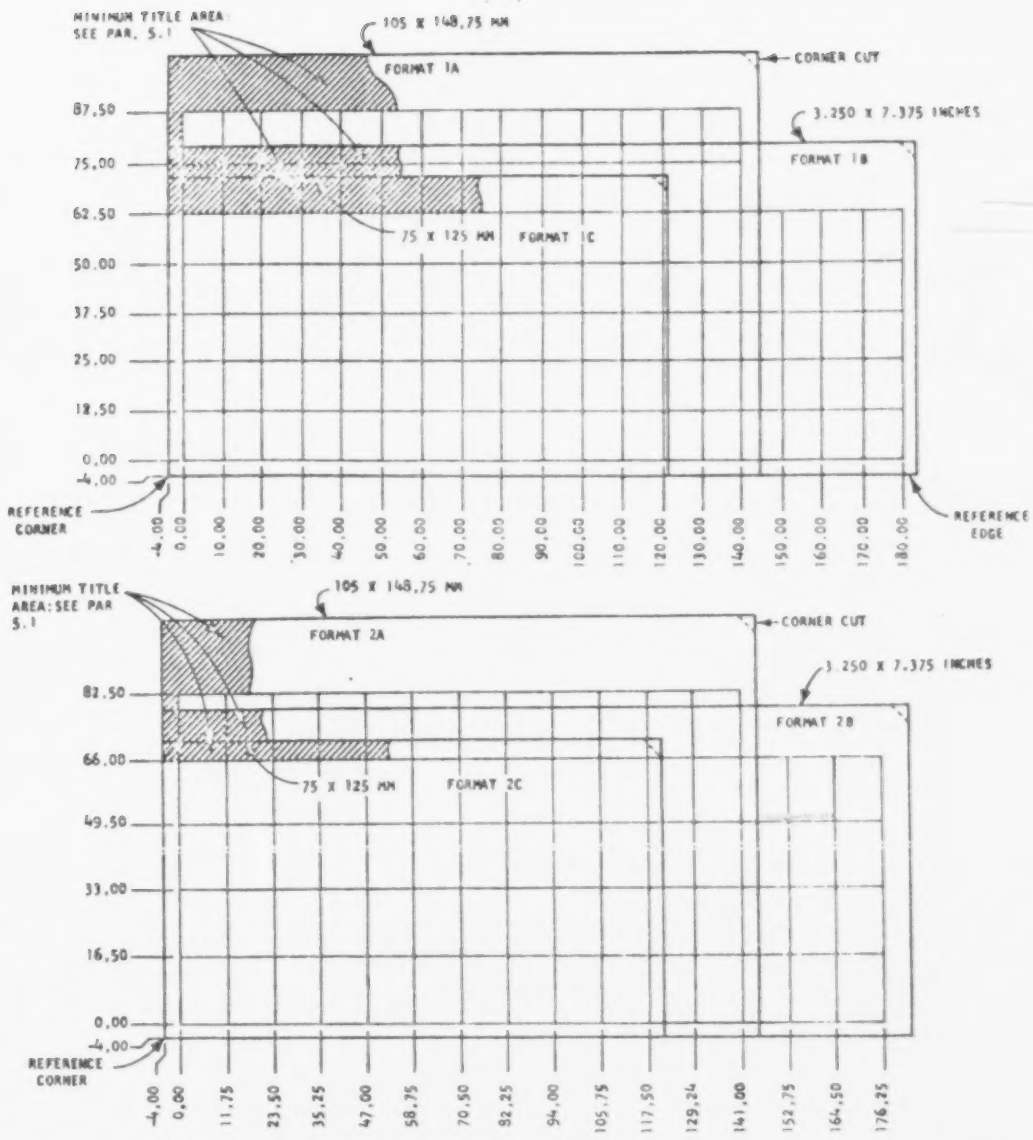
## 4.4 MICROIMAGING SYSTEMS

A microfiche is a sheet of transparent material upon which an array of miniaturized images, usually of document or book pages, has been reproduced. The process of making the original microfiche involves specialized photographic equipment, such as step-and-repeat cameras and high resolution silver-halide film. However, once a satisfactory original is available, copies may be made cheaply and simply by contact printing on diazo, silver, or thermal copy films.

NASA and the AEC were among the earliest Federal government agencies to use microfiche for the dissemination of technical reports, although they have long been popular in Europe as a medium for out-of-print books and other scholarly materials.

The original NASA format placed 60 images on a 5 x 8-inch microfiche, while the AEC used a 3 x 5-inch format. However, the government's Committee on Scientific and Technical Information (COSATI) standardized on a 4 x 6-inch microfiche for the dissemination of technical reports (188). As shown in Figure 13, from 60 to 72 images of 8-1/2 x 11-inch pages can be arrayed on each fiche at an 18 to 20X reduction. Also, the 4 x 6-inch size is compatible with the international standard of 105 x 148.75 mm, but the 5 x 8-inch format does not have a corresponding international standard.

The National Microfilm Association (NMA) in their Standard Specification M-1-1967 (189) recognizes three sizes of fiche, and two different




NOTES:
1. Dimensions are in Millimeters except as noted.
2. Line width is 0.25mm.
3. Dimensions are to center of lines.
4. Tolerance on position of grid line is ± 0.025mm.
5. Tolerance on left and bottom margins 4mm ± 0.5mm.
6. Corner cut-right, odd generation microfiche; left, even generation.

(Diagrams shown approximately 60% of full size)

| Format | Nominal Fiche Dimensions | No. of Rows | No. of Columns | Total No. of Image Spaces first card | Total No. of Image Spaces follow-on cards |
|---|---|---|---|---|---|
| 1A | 4 x 6" | 7-8 | 14 | 98 | 112 |
| 1B(tab card) | 3-1/4 x 7-3/8" | 5-6 | 18 | 90 | 108 |
| 1C | 3 x 5" | 5-6 | 12 | 60 | 72 |
| 2A | 4 x 6" | 5-6 | 12 | 60 | 72 |
| 2B(tab card) | 3-1/4 x 7-3/8" | 4-5 | 15 | 60 | 75 |
| 2C | 3 x 5" | 4-5 | 10 | 40 | 50 |

Figure 13: NMA Microfiche Standard (Specification M-1-1967)

grid patterns (see Figure 13). However, there is nothing said about the reduction ratios to be employed--the important thing is the relation of the image dimensions to the optical system of the reader. The reduction is varied to fit different original sized pages into the fixed grid.

It might seem reasonable that when the U. S. government sets up a standard, manufacturers would follow along. But in a rapidly changing technology--which microforms certainly are--it is extremely difficult and perhaps undesirable to freeze current practice into a standard which might substantially underrate the future capabilities of the medium (see Table 10). For instance, many fiche users have found it desirable to pack up to 98 pages into the same 4 x 6-inch area for disseminating catalog pages, parts lists, etc (see Figure 13). However, this may require reductions up to 24X, and most microfiche readers cannot handle a range of enlargement from 18X to 24X satisfactorily with a single lens and fixed screen size.

4.4.1 UMF: Ultramicrofiche

The idea of using extreme reduction ratios--several hundred to one--has long intrigued microimaging workers. A visionary proposal along these lines was made by Hays in his "A Billion Books for Education in America and the World" (190).

Hays proposed using a 200X reduction to place 2000 pages on a 4 x 6-inch fiche. Then, a million-volume library of 200 million pages could be contained in 100,000 fiche, and stored and shipped in a 4- by 6- by 2-foot cabinet. A copy of any fiche could be produced for as little as $1, if copyright laws permitted, for a user cost of only 0.04¢ per page.

TABLE 10 : CURRENT & PROJECTED MICRO

| | COSATI Microfiche (1964?) | Billion Books (Proposal) (1967) | Microbook (Proposal) (1968?) | TIM (1968?) | NCR Ed'n Prod's Ultrafiche (1970) | |
|---|---|---|---|---|---|---|
| Imaging Technology | silver halide, diazo | — | — | PCMI | PCMI | |
| Resolution, lines/mm | 125 - 250 | — | — | 1000 | 1000 | 500 |
| Linear Reduction range | 18 - 20X | 200X | 42X | 150X | 100-225X (120X typical) | |
| Original Material | tech. repts. | packaged libraries | books | eng. prod. info. | library collection | |
| Page Dimensions | 8½ x 11" | 6 x 9" | 6 x 9" | variable | 6 x 9" | |
| Total Pages per Item | up to sev. 100 | av. 350 (up to 1000) | av. 350 (up to 1000) | — | av. 350 (up to 1000) | |
| Total No. of Items | $10^6$ | $10^6$ | — | — | $3.5 \times 10^3$ books | |
| Total Pages | $10^8 - 10^9$ | $10^9$ | — | $4 \times 10^5$ | $10^6$ | |
| Dissemination Microform | fiche | UMF | fiche | UMF | UMF | |
| Polarity | negative | — | — | — | positive | |
| Dimensions & Area | 4 x 6"=24 sq. in. | 4 x 6 = 24 or 5 x 8 = 40 | 4 x 6"=24 sq. in. | 4 x 6"=24 sq. in. | 4 x 6"=24 sq. in. | 1 |
| No. of Pages per Fiche | 60 - 72 | 2000 - 3000 | 450 | 3000 - 5000 | up to 3500 | |
| No. of Pages per sq. in. | 3 | 75 - 120 | 15 | 125 - 200 | 175 | |
| Total Fiche per Item | 1 - 10 | 0.1 | 1 - 2 | — | 0.1 - 0.15 | |
| Total Fiche in Collection | — | $10^5$ | — | 7 | 500 | |
| Other | | | | replaced 2X a year | 5 collections | |
| Reading Devices | | | | | desk model $650 | |
| Reader | $75 - $500 | $150 | — | — | portable model $3 | |
| Reader-Printer | | | | | $2950 | |
| Price of Service | | | library master | copies | $3000/year | $5600/year (5 collections) |
| Per Fiche, $ | 0.25 - 0.75 | 0.75 | 1.25 | 0.20 | 20 | 10.50 |
| Per Page, ¢ | 0.3 - 1 | 0.04 | 0.25 | 0.05 | 0.4 - 0.7 | 0.35 |

Abbreviations: COSATI: Committee on Scientific and Technical Information
EBR: electron-beam recording
EK: Eastman Kodak Co.
EVR: Electronic Video Recording (CBS, Inc.)
LRI: Library Resources, Inc. (Encyclopedia Brittanica, Inc.)
MDS: Microform Data Systems
NCR: National Cash Register
PCMI: photochromic microimaging
TIM: Technical Information on Microfilm, Ltd.

ICHE AND UMF SYSTEMS, AND A COMPARISON WITH EVR

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| Microtech Press Microaperture (proposal) (1970) | LRI Microbook™ (1971) | MDS Ultrastrip (prototype) (1971) | EK (prototype) | Ultramicrotape (proposal) | CBS EVR (1970) |
|---|---|---|---|---|---|
| silver halide | silver halide | silver halide | Photo-resist | EBR on silver halide | EBR on silver halide |
| 800(release copies) | — | — | 2,000(original) | $10^3$ - $5\times10^4$X | 800 |
| 150X | 50 - 90X (70X typical) | 150 - 230X | 700X | | 80 - 125X |
| books | library collection | documents | encyclopedia* | packaged libraries* | TV programs |
| 8½ x 11" | 6 x 9" | 8½ x 11" | 8½ x 11" | — | — |
| up to 400 | av. 350 (up to 1000) | — | ~800 | — | 2 programs (black & white) |
| — | $2\times10^4$vols†($1.2\times10^4$titles) | — | 24 vols | $10^6$ | — |
| — | $6\times10^6$ | $10^5$ on line | ~20,000 | $10^9$ | — |
| microaperture | UMF positive | Ultrastrip (6" of 35mm film) | plate | — | Cartridges positive |
| — | 3 x 5"=15 sq. in. | 1.4 x 6"=8.4 sq. in. | — | — | 1/3 in. x 750 ft.= 3000 sq. in. |
| x 1⅛"=1.8 sq.in. | up to 1000 | 2000 | 2.5 x 2.5"=6.25 sq. in. | — | $1.8\times10^5$ frames |
| 400 | 75 | 240 - 400 | ~20000 | — | 60 |
| 220 | 1 - 2 | — | ~3000 | — | — |
| 1 | 12000 | — | 1 | — | — |
| — | one fiche per title | uses tech. dev. by Republic Microvue | — | — | sound, color capability |
| — | desk model (DuKane) lap model(Technicolor) | MINDEX | — | — | Teleplayer‡ $750 |
| — | $21,000/collect'n | $50/orig. master | — | — | 25-50 per cartridge |
| | orig. 1.75 / replac. 1 | 0.30/copy | | | 0.15 - 0.3 |
| | 0.35 / 0.1 | | | | |

†$10^6$ vols projected for entire series

*Long-range conception

‡Standard TV set necessary, $50 - $500

By this means, an entire library of a million volumes could be placed in 1000 locations at a total cost of $581 million, or only $581,000 per library. To distribute the same material in conventional form would cost at least $30 million per library, according to Hays.

In 1968 or 1969, EDUCOM proposed using a 42X reduction to place up to 450 6 x 9-inch book pages on a 4 x 6-inch fiche. This book-per-fiche concept, dubbed "microbook", was to employ an innovative dissemination scheme: libraries would purchase masters for $1.25 each, and would be allowed to make up to 12 copies locally under a limited copyright, to be sold to users for only 20¢ per copy. The microbook concept could lead to a new industry: micropublishing (191, 192).

In this report, "ultramicrofiche" (UMF) will be differentiated from microfiche by arbitrarily restricting the UMF designation to fiche using reductions greater than 50X. Others have proposed dividing at 100X or 200X, but this excludes most present systems, except those based on photochromic microimage (PCMI) technology. A better UMF criterion is the use of a two-stage reduction. While it is not difficult to achieve 30 to 40X at a single step, technical problems become severe above this, and it is much better practice to make an original microfiche at a moderate reduction (5 to 15X), and from this make a master fiche by another step of 10 to 20X, to achieve an over-all reduction of from 50 to 300X.

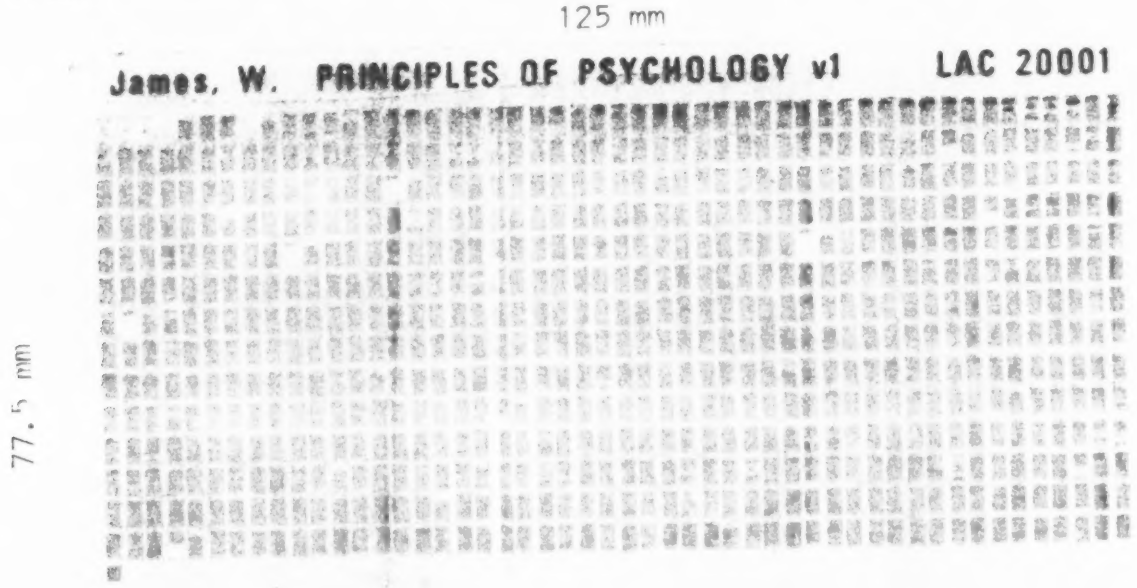
Microbook libraries have become a reality with the formation of Library Resources Inc. (LRI) by Encyclopedia Britannica (EB). The initial offering in the Microbook™ Library Series is a 20,000-volume "Library of American Civilization: Beginnings to 1914" (193). EB has taken many twists and turns in its attempts to devise a suitable

format. Apparently, they began their search with 3 x 5-inch PCMI. However, they eventually awarded Image Enterprises, Inc. of Los Angeles a $4 million contract to produce UMF and readers for LRI. They plan to employ a two-step reduction which will achieve between 50 and 90X, depending on the size of the original pages. If a standard book-opening is the original, the reduction will be about 70X. Only one book will be placed on each 3 x 5-inch fiche, which holds up to 1000 images (see Figure 14).

The basic price of the "Library of American Civilization" is $21,000, including all Microbooks, five sets of book-form catalogs, five sets of book-form bibliographies (dubbed Biblioguides™) and research guides, and 20 sets of microfiche catalogs and Biblioguides. Duplicate or replacement Microbooks will be supplied on request by sending a pre-printed postcard to Library Resources, Inc.

NCR's PCMI (photochromic microimage) is the oldest practicable UMF technology, and has been used in this country by Sears, Roebuck and Ford Motor Company for disseminating their vast parts catalogs. However, PCMI's first public use has been in England, where TIM (Technical Information on Microfilm, Ltd.) offers a "microfile" system for engineering product information (194). By mid-1969, TIM claimed to have installed 500 such systems. Each TIM 4 x 6-inch UMF contains at least 3000 pages at 150X. The complete service is rented for £ 133 (about $300) per year, including a reader and two microfiles ("Product Selectors and Data", and "Suppliers Information"). Because these microfiles are contained on only seven UMF, they can be updated every six months simply by replacing all the UMF.

LRI Microbook: up to 20 rows by 25 2-page columns = 1000 pp. (max.)
Each microimaged page is approximately 2.2 x 3.5 mm at 70X. Even at the moderate reduction of the Microbook format, a microimaged book page is no bigger than one letter of the eye-readable title.


125 mm
77.5 mm
James, W. PRINCIPLES OF PSYCHOLOGY v1 LAC 20001
A MICROBOOK by Library Resources, Inc. An Encyclopaedia Britannica Company

NCR PCMI Ultrafiche: up to 35 rows x 48 2-page columns = 3360 pp. (max.)
Each microimaged page is approximately 1.25 x 2 mm at 120X.

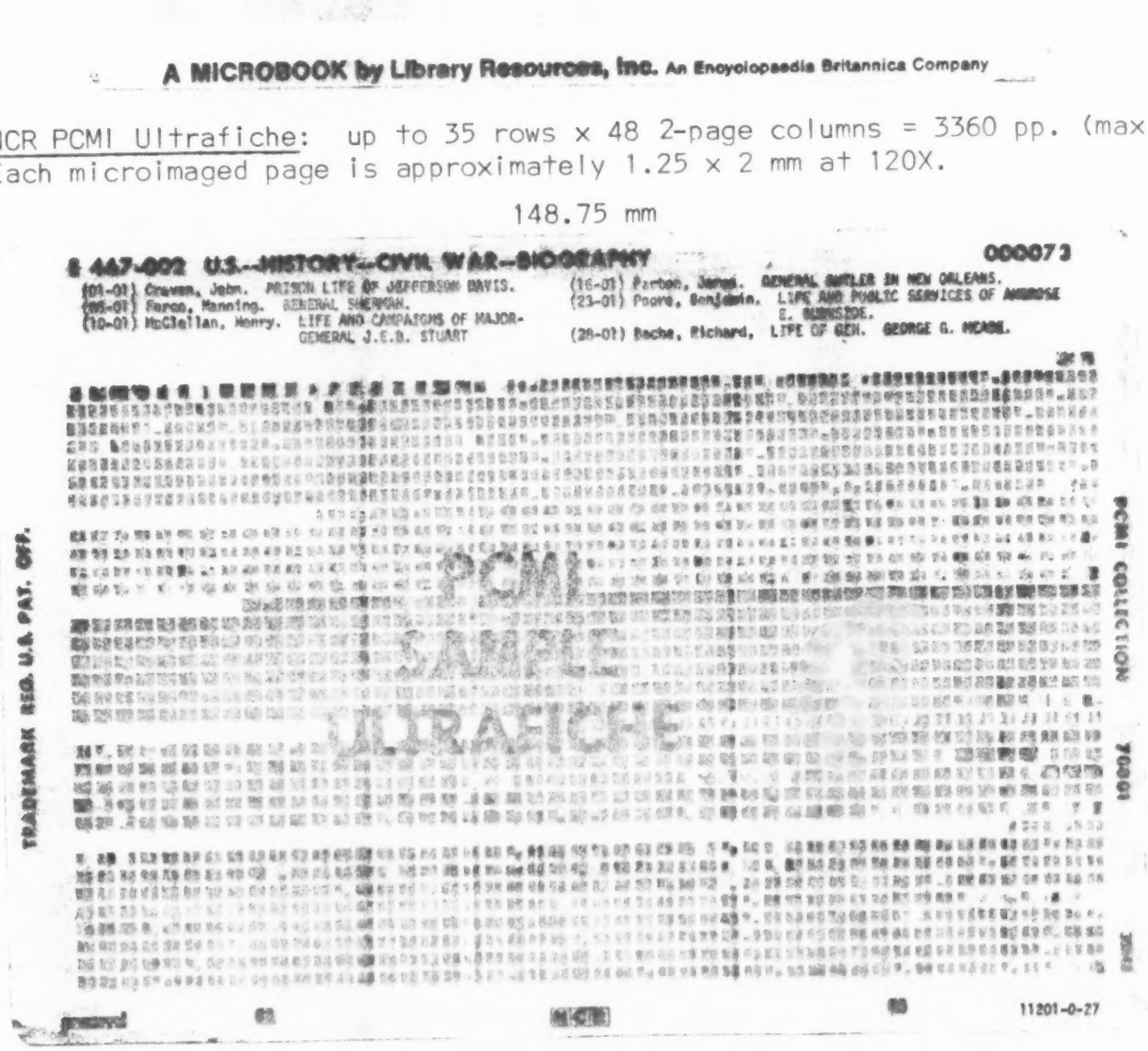

148.75 mm
105 mm
000073
(01-01) Craven, John. PRISON LIFE OF JEFFERSON DAVIS.
(05-01) Force, Manning. GENERAL SHERMAN.
(10-01) McClellan, Henry. LIFE AND CAMPAIGNS OF MAJOR-GENERAL J.E.B. STUART
(16-01) Parton, James. GENERAL BUTLER IN NEW ORLEANS.
(23-01) Poore, Benjamin. LIFE AND PUBLIC SERVICES OF AMBROSE E. BURNSIDE.
(28-01) Roche, Richard, LIFE OF GEN. GEORGE G. MEADE.
PCMI
IMAGE
ULTRAFICHE
TRADEMARK REG. U.S. PAT. OFF.
PCMI COLLECTION 70001
11201-0-27

Figure 14 :Current UMF Formats

NCR has recently decided to market PCMI "ultrafiche" (as they call them) in this country (195). Each 4 x 6-inch ultrafiche holds from 7 to 10 books, or up to 3500 pages at 120X (see Figure 14). Initial offerings are to include five library collections: American Civilization (196); Literature--Humanities; Social Sciences; Science and Technology; and Government Documents. Each collection till include about 700 books on 100 ultrafiche, for a price of $1200. They also have a "College Bound" collection of 500 books for $550, and a "College Catalog Service" of 500 catalogs for $250.

At the time that NCR was developing their PCMI technology in the early 1960's, Republic Aviation Corporation was working on a two-step silver-halide technology which was to be capable of over 200X, called Microvue. This system never was marketed successfully by Republic, but is now available from Microform Data Systems, Inc., Mountain View, California. Their basic storage unit is a six-inch-long strip of 35-mm microfilm, which they call Ultrastrip (197). Each Ultrastrip can hold 2000 8½ x 11-inch pages at 210X. Two types of originals are proposed for input: hard copy pages put onto primary microfilm via planetary camera, or computer-output microfilm (COM). The primary microfilm at from 16 to 24X from either of these sources is further reduced about 10X in the M/790 Ultrafilm Compositor Recorder, a numerically-controlled device recording stroboscopically at 5,400 frames per hour. The Ultrafilm is processed and copies made in manual or automatic-stepping contact printers; the latter can produce from 300 to 600 Ultrastrips per hour.

Three types of readers are available. The MINDEX/340 is semi-automatic; and the 370 and 380 are fully automatic, using cartridges

holding 10 or 20 strips, respectively, and offering magnifications of from 150 to 230X. The 370 has an optional video display attachment for use with computer data. Both automatic readers use keyboards for random access image selection, the 370 locating and displaying any of 20,000 pages in less than 6 seconds, and the 380 any of 40,000 pages in 3 seconds.

Still another approach to the microbook is the "microaperture", a single frame of 35-mm microfilm holding up to 400 pages at 150X, and mounted in a standard "Mil-D" aperture card. Advantages claimed for this approach are easy manual handling; a uniform location grid (four 100-page quadrants); and the availability of 90% of both surfaces of the card for human-readable information. A description of this proposed system has been published, and contains a great deal of information on how high-reduction microforms are created and used. It is particularly notable for its description of a reader with a microaperture page registrator, which uses eight keys in combination to locate any of the 400 images mechanically (198).

Even 200X is not near the limit of microimaging technology. For example, Eastman Kodak has developed a process which uses a photosensitive resist and high-resolution plates, whose resolving power is in excess of 50,000 lines per inch (2000 lines per mm) (199). They claim that such an imaging medium makes possible the storing of an entire 24-volume encyclopedia on a 2-1/2 x 2-1/2-inch plate. This would be equivalent to a 700X reduction.

H. Ferńandez-Morán has proposed a 100Å-resolution "ultramicrotape" system, based on techniques developed for electron microscopy (200). This would be a considerable step from present COM technology (see Section 4.4.3).

In this system, an electron microbeam probe would engrave texts on thin collodian film at demagnifications of from 1,000 to 50,000X. At the latter reduction, a 10-million-volume library could fit onto this page--but the problems of locating and utilizing information at such recording densities will be very difficult to solve.

UMF does not appear to offer significant per-page savings over conventional microfiche at this time. Table 10 shows that on a per-page basis, UMF will cost 0.35 cent a page as compared to 0.3 to 1 cent for ordinary fiche. However, it should be pointed out that commercial UMF prices are being compared with government-subsidized microfiche. Eventually, ultramicrofiche technology will compete with conventional book and magazine publishing, conventional microforms, and even with conventional visual aids. However, audiovisual aids in UMF format will require spatial storage techniques yet to be developed for the audio portion.

There is also the possibility that one of the newest mediums, although primarily intended for audiovisual material, will enter into competition with UMF for the storage and retrieval of vast amounts of print material. This is EVR, or electronic video recording (201) (see Section 4.6.2.2).In the last column of Table 10, the characteristics of EVR as a reference medium are put into microimaging terms. On this basis, EVR competes favorably with present UMF technology--with the great additional virtue of compatibility with TV.

4.4.2 Microimaging and Television

At this time, no one can predict the eventual winners in the media battle to come. However, it seems certain that there will be more diversity and competition, rather than standardization. In conjunction

with some of these emerging technologies, television may become the preferred viewer interface. Television, with the addition of storage and response devices, offers the potential of a universal display window for all media, even though its resolution would appear too limited to handle microimages.

A marriage of TV and microimaging technologies is highly unlikely to occur simply by reducing existing print media photographically. While this provides economical storage, it may be very inconvenient to use. Instead, if the goal is to provide textual materials in a compatible visual form--what may be called "telereading", or reading the printed word from a TV screen--suitable formats and equipment must be developed in a unified way (202).

The time-honored book-page format was invented a few centuries ago as a solution to the problem of manual access to long scrolls. However, in reading from a television screen, the page is irrelevant.

What is required is the ability to present the eye with a succession of words and sentences. Techniques for doing this were developed a long time ago for motion pictures, and are in wide use in television today. They are called "rolling titles" or, in television, "crawls", and cause words and sentences to appear to move horizontally or vertically in relation to the screen. In addition to this capability, control over size, contrast, and speed of presentation would be useful.

Another marriage--between microimaging and computer technology--may provide the answer to the vast recomposition that will be required to convert existing textual matter for telereading.

4.4.3 COM: Computer-Output Microfilm

The product resulting from the conversion of digital data to human-readable microfilm is called computer-output microfilm (COM). The idea is quite simple, but has been difficult to incorporate into a marketable product. Computer-manipulated and generated information, instead of driving a mechanical-impact printer, is made to control the movement of an electron beam. In turn, the tracings of the beam are recorded on microfilm, which is then conventionally developed, and read in microfilm readers.

COM units on the market use several variations of electronic recording: cathode-ray tube (CRT) recording; direct electron-beam recording (EBR); or CRT with fibre optics. CRT-based COM's operate like kinescoping in television, but record with a microfilm camera instead of a motion picture camera. EBR systems form a latent image directly on dry-silver microfilm as it passes through an evacuated chamber, thus avoiding an optical interface, and CRTs with fibre-optics faceplates can use contact-printing techniques.

A COM unit may be driven direct by a computer, but many users find they can achieve better flexibility and more effective utilization via computer-compatible magnetic tape units. Reductions employed in COM practice are usually higher than COSATI microfiche, but do not yet reach those found in UMF practice. Usually, 24X and 42X are employed. At the latter reduction, the equivalent of 208 11 x 14-inch pages (in 13 rows and 16 columns) may be placed within a 6-inch length of 105-mm wide film. The developed film can then be cut up into 4 x 6-inch fiche. In one of the first books on the subject, Avedon (203) states that a typical COM recorder can place the equivalent of 30,000 pages

per hour on microfilm. This is 5000X the speed of an automatically driven electric typewriter operating at 15 characters per second.

For document distribution, a properly designed COM system can provide dramatic savings over paper copies (204). For example, multiple runs on a line printer using carbon-manifold forms costs at least two cents per page. The same information can be recorded on a 16-mm microfilm master in a COM recorder, and contact distribution copies made at costs of approximately 0.1 cent per page--a saving of twenty times. However, this does not include the necessary cost of user equipment for reading the microfilm.

Most COM users duplicate their microfilm output on a non-silver-halide material, such as diazo or Kalvar microfilm, and insert these copies in cassettes. The 16-mm microfilm cassettes may then be used in automatically driven reader mechanisms, in which they can be searched rapidly by manual or automatic means. Unfortunately, the cassettes are seldom interchangeable in different manufacturers' readers.

The COM field is so new that there is a great proliferation of devices and systems, Avedon listing nineteen companies as marketing COM recorders (203). The first COM units have cost several hundred thousand dollars each, but several are now on the market for less than $50,000 (205).

The potential of the COM field goes far beyond the initial application of reducing the bulk and cost of computer print-outs. Many of the more sophisticated COM units are capable of vector generation, which enables them to act as x-y plotters, and some units can generate tones and even colors. Coupled with ever more sophisticated

computer hardware and software, tomorrow's COM units may become the preferred method of composition for materials which are normally typeset or hand-drawn. Coupled with emerging UMF technology, dramatic price drops for distribution copies of all kinds of recorded materials are likely to be forthcoming. Advanced COM-like systems, like Scanimate and Animac could also have an impact on the audio-visual market (see Section 3.3 ).

Eventually, COM units could provide a versatile recording capability for satellite-transmitted digitally encoded reference information. Centralized data banks of current educational information could be kept on digital magnetic disc and tape units. This information could be transmitted at very high speed over wideband satellite links to ground receiving stations, which, after demodulation, could record the digital information on magnetic tape. This information could be then further processed on local computers and/or put into human-readable microforms on-demand via tape-driven COM units.

## 4.5 WIRED TELEVISION SYSTEMS

### 4.5.1 Picturephone

The American Telephone and Telegraph Company recently initiated its long-awaited video telephone service, called Picturephone® (148). Initial intercity service was slated between Pittsburgh and New York City, but New York's deteriorating telephone service has delayed the inauguration of Picturephone. Local service was begun in Pittsburgh in 1970, and an intercity link to Chicago is scheduled for spring 1971. Considering the effort that has been made to add vision to the telephone, and the considerations given

to applications of such service, Picturephone may have as great an impact upon our modes of communication as did the origination of telephone service some 75 years ago.

Picturephone may play a crucial role in the competition between communications and transportation. Although Picturephone employs a sophisticated audio-video terminal set, it is to be phased in without radically changing the telephone network (148). Locally, Picturephone is transmitted over a 6-wire loop and switched by AT&T's No. 5 crossbar system. The voice portion uses one pair of telephone wires, and the picture portion requires two more pairs--one pair for transmission in each direction. This seems little to pay for the advantages of having both sight and sound. However, although a Picturephone circuit only uses 3 pairs of wires physically, this is the equivalent of up to 300 carrier-modulated telephone channels.

Customers can make voice-only calls from a Picturephone set in the ordinary fashion with Touch-Tone® signaling. When they want to initiate a Picturephone call, they press a twelfth button on the handset, which establishes simultaneous two-wire telephone and four-wire video switching at the local central office. For transmission beyond a six-mile distance, picture, voice, and inter-office signal information are all digitally encoded and multiplexed into a composite 6.3 megabit-per-second (Mb/s) signal, using differential pulse-code modulation.

Initially, Picturephone service will emphasize face-to-face communication between two individuals, but equipment is being developed

to provide additional services. For example, a data set, appearing to the telephone network just like a Picturephone set, will enable Picturephone subscribers to call a computer, using Touch-Tone signals for input. Among the applications envisioned are simple computation, data retrieval, electronic banking, shopping services, etc. Also, access to different types of remote specialized information services may be obtained. Picturephone is capable of displaying a full set of alphanumeric characters, and simple graphs. Eventually, man-to-machine and machine-to-man communication applications may rival Picturephone's primary man-to-man communication use (206).

In addition to accessing commercial computer and information services, Picturephone is a near-ideal terminal for computer-assisted instruction. Few computer terminals available today have as versatile a mix of communication capabilities as does a Picturephone set. Presently available terminals usually provide keyboard input, with visual output or voice answer-back, but not both. With Picturephone, a variety of different stimulus-response combinations can accommodate different teaching-learning styles. The only potential rival to the Picturephone terminal for instructional use is two-way cable television (CATV) service. Picturephone versus CATV is expected to be one of the main internal communications subbattles in the rivalry between transportation and communications (see Section 4.7).

Regular telephone service is a compromise between audio fidelity and cost, and Picturephone is a compromise between picture fidelity and cost. The band of frequencies sent over the switched telephone network is limited to 300 to 3400 Hz, or less than one-fifth of the

full frequency range of human hearing, which may be taken as from 20 to 15,000 Hz. However, 3000 Hz seems to be an adequate range for conversational purposes.

The spread between the range of human vision and Picturephone capability is similar. The unaided human eye is capable of resolving points as close together as 1 minute or arc--equivalent to 4 line-pairs per millimeter at a Picturephone viewing distance of 90 centimeters. Therefore, Picturephone's 12.5-centimeter screen width could usefully accommodate 500 picture elements linearly, or about 1/4 million black-and-white picture elements within a square screen area, if its capability were to equal human visual acuity. Furthermore, the eye can distinguish approximately 10 levels of tonal variation on an absolute basis, and considerably more on a relative basis.

Neglecting this, and using only the acuity criterion, in a 1 MHz bandwidth, Picturephone, using 250 active lines per frame and 30 frames-per-second, can provide only about 150 picture elements per line, or 37,500 elements within the screen area--about one-sixth of the capability of monotonal vision, i.e. no grey scale.

Commercial television provides a picture four times better than Picturephone--but it requires more than four times the bandwidth. However, because most families own at least one television set, and none yet have Picturephone service, it is reasonable to ask if this vast investment in existing TV equipment couldn't be adapted as terminal equipment for Picturephone service.

Broadcast television is not likely to accomplish this, because of its asymmetrical communications design. That is, in most communities,

from 2 to at most 10 powerful broadcast stations send signals omni-directionally to up to several million viewing locations, but no provision is made for any return signals. Furthermore, the higher the broadcasting antenna can be placed, the greater the number of viewers who can receive an acceptable signal. Thus, broadcasters tend to share one or two antennas placed at the highest point in a locality. Thus, commercial television is largely a point-to-area communication system, and at the opposite extreme from points-to-points systems, such as the switched telephone network. Some sort of network could be added to broadcast television, but this would require broadband links to individual sets from a central distribution point. Such systems exist in the form of community antenna or cable television, both terms being abbreviated to CATV in common usage.

4.5.2 Cable Television

CATV is a technological development whose ultimate impact may reach far beyond its original purpose of program redistribution. Telephone companies originally welcomed fledgling CATV operators who wanted to rent pole space for their cables, but they eventually realized that a coaxial cable going into every home could obsolete their wire-based service. The simple twisted pair of the phone company would be paralleled by a sophisticated coaxial cable capable of carrying thousands of telephone conversations simultaneously--or their equivalent in video telephone, facsimile, interactive computer, electronic banking, and other innovative services--which the phone company hopes Picturephone will capture.

However, CATV started out as a simple response to the desires of television viewers in poor reception locations for a good picture. Major capital cost items in CATV systems are the headend, which usually consists of a tower, a receiving antenna, and amplifier; distribution lines, which contain coaxial cables and their associated amplifiers and filters; and smaller coaxial cables, which are "dropped" off the main line to serve individual subscribers. Initially, cable companies were content just to act as relays, picking up distant broadcast signals, amplifying them, and distributing a signal of greatly increased quality to their subscribers. Of course, an antenna atop a tall tower could also pick up more different signals than a home owner could hope to get, even with a $50 to $100 antenna. CATV thus offered both quality and quantity advantages.

Today, one coaxial cable can provide a bandwidth of 300 MHz, capable of transmitting from 20 to 40 high-quality television channels without using up any scarce spectrum space. Also, because the signals in a CATV system are confined to cables, they may be routed selectively by filtering techniques (207). Thus, diverse public, private, and even interactive services can be provided.

Barnett has reviewed a number of these, such as traffic surveillance and control; police, health, and emergency services; automatic utility accounting; facsimile-based mail, newspaper, and library service; video cassette library service; community communications for minority and other special interest groups; pre-school, in-school, and adult education; employment exchange service; etc.(208). The list of

potential applications is endless, because the communication channel is so wide; because "wired-city" connections can be rearranged to suit changing conditions; and because extensive user interaction is possible (209, 210).

Because of the way it developed, CATV was unregulated at the beginning. CATV operators were neither broadcasters nor common carriers. However, as the enormous potential of cable has become recognized, various governmental agencies have stepped in to award territorial franchises, and to attempt to regulate the cable companies (211).

One of the most complex situations is in New York, where city, state, and Federal regulatory bodies all claim jurisdiction. A recent report to the State of New York Public Service Commission presents a great deal of information about the CATV industry, its growth and costs, and its competitive impact on broadcasters and common carriers--as well as the case for state regulation (212).

4.5.3 A Comparison Between Picturephone and CATV

It is of interest to compare and contrast these two new wideband services. Today, CATV companies provide their customers with a one-way service providing something like ten high-quality color television program choices, for $5 to $10 a month. In addition to this, the amortized cost of the TV set and its upkeep and electricity supply may add another $10 a month.

On the other hand, Picturephone service inherently offers two-way communication with an ever-increasing number of sources, but has low picture quality and no color capability at present. Pittsburgh customers pay $160 for a Picturephone set, including one-half hour of

local use per month. After this initial period, the cost is 25 cents per minute (213). Thus, a businessman who used his Picturephone set an average of 1 hour per day, or 20 hours per month, would pay a total of about $450, or over $22 per hour. The same businessman would only pay $20 to $30 a month, or $1 to $1.50 per hour on the same basis for local telephone service. Therefore, if it is to be widely accepted, Picture-phone must provide from 15 to 22 times the value or utility of today's telephone service--or the price must come down.

The main purposes of Picturephone and CATV are quite different, but it is worth contrasting them so that the unique place of each may be better understood.

A major difference is that each Picturephone set has a built-in television camera and microphone. The user can change focal lengths from a normal setting of 3 feet to 20 feet to take in two or three faces, or direct it down by a mirror at a chart only 1 foot away. The iris automatically adjusts according to the ambient illumination. To provide such a capability for CATV would double or triple sub-scriber costs, and there is little chance of this happening in the forseeable future.

Also, CATV companies are not likely to assume the responsibilities of a common carrier; that is, they will not be required to provide service to all users no matter how sparse their locations may be. Thus, it seems very unlikely that CATV will reach as large a portion of the population as present telephone service, nor will Picturephone be desired by all present telephone subscribers.

Furthermore, CATV companies will not provide long-distance person-to-person interaction, which is likely to be Picturephone's forte, while on the other hand the telephone company is not contemplating the provision of entertainment programs.

However, some CATV firms are considering the provision of a minimal subscriber response capability, such as a set of push-buttons. This would enable a variety of querying, polling, and ordering services to be initiated (156, 214, 215).

Another way that Picturephone and CATV may be compared is to consider the number of hours of use expected. From Figures 8 and 9, it is estimated that 180 billion calls were made from 105 million telephones during 1970, or 1700 calls per phone. This is an average of 5 calls per day per telephone. If the average duration of each call is 5 minutes, the utilization of the average telephone set is less than half an hour per day. Whether Picturephone will raise or lower this total is problematical, but to the extent that using Picturephone replaces some transportation for day-to-day transactions, utilization might reach two hours a day per Picturephone set, particularly if instructional and interactional situations became attractive. Then, utilization would be about 1/3 that of television, which is $5\frac{1}{2}$ hours per day in the average home (216). In business and industry, telephone use is much higher--perhaps two to three times the average, or more than an hour per workday. Of course, a good portion of this is accounted for by within-company (interoffice) calls. With the addition of Picturephone service, the time spent on this mode of communication could increase two or three times to perhaps three hours per workday, but still only about half of television use.

Because of these wide differences in purpose, capacity, and cost, it is difficult to predict whether Picturephone or CATV will have the greatest effect in education. If cable companies add a response capability, CATV will be more attractive for educational utilization. This capability may be encouraged by government, following the precedent set by municipalities granting CATV franchises only upon the condition that at least one channel be assigned to education.

4.5.4 Communication Satellite Implications for Picturephone and CATV

In all likelihood, domestic communication satellite services will not be permitted to compete directly with existing services. At least in its initial phases, communication satellite service is likely to complement them (217). Using communication satellite signals, local CATV systems could eventually bring in program materials from all over the world, and redistribute them to their customers locally (218). Similarly, with the aid of communication satellites, telephone companies could extend Picturephone service to individuals and businesses on a real-time world-wide basis.

However, in some instances, communication satellites are an alternative to hard-wired communication systems, such as telephone lines or coaxial cable. Wire and wireless have always competed, but each has tended to stake out a distinct market in the past. F. C. McLean, in his 1966 Granada Hall Lecture, "Telecommunications--The Next Ten Years", has said that:

> "For any communication problem the first point to be settled is whether it is better to carry out the communication by radio waves or whether to do it with wires. Wires, of course, were the first in the field, being used from the invention of the electric telegraphy in the early nineteenth century...Radio started toward the end of the nineteenth century and since then there has been a continual see-saw

in all aspects of the communication fields between the wire and radio circuit. Transatlantic communication started with wire with the telegraph cable, then moved to radio for the first of the transatlantic telephone circuits, and it now seems firmly established by wire with the latest cables with amplifiers in them. It would be a foolish man however who would say that radio would never come back into such transatlantic traffic...we see on one hand enormous investment in satellites and their associated ground stations, and on the other large and long-time investments in cables and in new cable-laying ships going on at the same time.

"For conditions of very high density traffic between two points, the wire, whether it is an actual wire or a tube conveying electric waves, seems to have an economic advantage. This advantage grows as methods are found of imposing not a single message but perhaps thousands of messages on a single wire or conducting tube. But for traffic of lower density and over difficult terrains radited signals seem to have the advantage....

"For the conveyance of messages to a widespread audience, as in broadcasting, radited waves seem to have, except in special conditions..., a very definite advantage. It represents the quickest, and by far the cheapest, way of bringing messages, whatever their content, to the individual and is much cheaper than the printed word or letters....

"In the very long term, we have to expect that nearly all services to and from fixed points will be by wire and that all radited services will only be used for communication to and from moving objects. It will, however, be at least 50 years before this stage of telecommunication development is reached." (219)

Similarly, it is exceedingly difficult to see how the future educational communications market will divide itself between communication systems--satellite-based or not--and physical transport of program materials. In particular, the rapidly developing technology of low-cost video storage will compete with many electronic systems in the near future.

## 4.6 CASSETTE AND DISC PROGRAM STORAGE SYSTEMS

Currently, many new products and systems are being announced for electronic and physical distribution of program material. Probably,

none has had as great an impact on the physical side as has the Philips audio cassette, an ingenious, low-cost miniaturization of reel-to-reel recording which eliminates tape-threading. In just a few years since its introduction, it has become a reproduction medium for audio second only to disc (220), and undoubtedly the most widely used audio-recording medium for the general public.

There is considerable confusion between the terms "cassette" and "cartridge" in relation to film and tape packaging systems. The Philips audio cassette is a two-hub device (see Figure 15) in which the tape only leaves the confines of the enclosure when passing over the record/reproduce head (221). In contrast, most cartridges are one-hub enclosures from which tape or film is drawn past a record/reproduce head. Some contain a continuous-loop of tape (Orrtronics, Fidelpac, Lear) or film (Technicolor), so that after playing, the tape or film is at its beginning position. Other film cartridges must be rewound back into the cartridge (Kodak, Bell and Howell). Some of the new video cartridge/cassette systems will use variants of the 2-hub design, some will use 2 reels coaxially mounted, and some will use 1-hub cartridges. Thus, it appears that the lack of standardization in the video field will be even greater than in the audio market (222).

The reasons for Philips success may be understood best when put in the context of earlier tape packaging efforts, such as the basically similar RCA cassette, which appeared in the early 1960's. Perhaps RCA was ahead of its time, perhaps their design was not reliable, or perhaps they never could develop the right marketing technique. Also, they never succeeded in getting anyone else to use their design, whether intentionally or not.

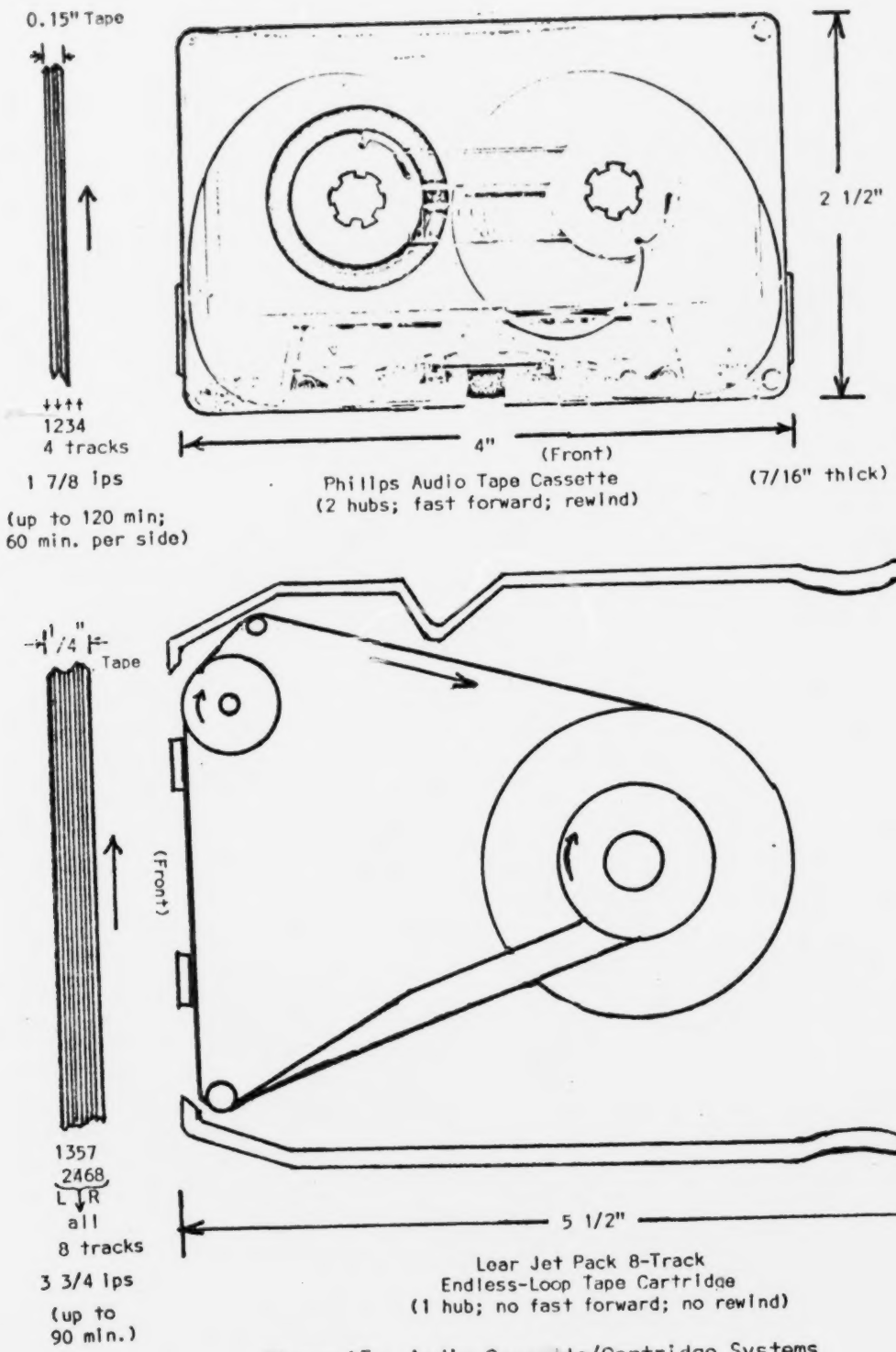



Figure 15: Audio Cassette/Cartridge Systems

On the other hand, Philips, a giant Dutch-based electrical company, set out deliberately to give their design to all firms willing to agree to use it in a compatible fashion, free of charge. This was unheard of in a world where many manufacturers seek to "lock out" competition by keeping a design to themselves, or licensing it only for a large royalty.

4.6.1 The Philips Audiotape Cassette

Figure 12 shows the Philips cassette full-size. It is 10 cm long, 6.3 cm wide, and only 1.1 cm thick (at its thickest part). Yet it can hold up to 650 feet of 4-mm (0.15-inch) wide, 0.3-to 0.5-mil thick magnetic tape. And because tape speed is only 1-7/8 ips, up to 60 minutes of recording is available on each side. Blank cassettes of good quality net for from $1.00 (for 15 minutes per side) to $3.00 (60 minutes per side).

Prerecorded cassettes are available for from $4.00 to $6.00, and may become competitive with long-playing (LP) record prices, if their discount structure develops in a similar pattern. However, educators now get only 10 or 20% off on cassettes, compared to 40% to 50% on LPs.

Also, frequency range is usually limited to 10 KHz, and is likely to remain inferior to the best LPs for some time. However, at least one cassette manufacturer, TDK Electronics Corporation, claims a hi-fi range of from 30 Hz to 20 KHz with their Super Dynamic cassettes, and the Dolby noise reduction system is now being used to enhance the performance of all recording/reproducing systems (223).

Record/playback cassette tape recorders may be purchased for from $25 to $125, with stereo machines priced in a range above $80. Monaural playback-only machines may be obtained for less than $20. Portable, bettery-operated units made in Japan dominate the lower price ranges.

Increasingly, prerecorded cassette tapes for entertainment, instruction, information, and data transfer are being produced for this market.

Cassettes and cartridges have also proliferated in the audio-visual market, and in the new 16-mm COM (computer-output microfilm) market. They are now about to impact the vast markets related to television. However, the example set by Philips has not been learned, and most manufacturers of COM and video-cassette systems seem intent on "locking up" a segment of the market for themselves by devising media packages which can be used only on their equipment, and vice versa. The situation is so bad in 16-mm COM cartridges that there are over thirty competing formats on the market (224).

At the very least, these incompatibilities are a serious annoyance for many users, but they become critical when there is a need to adapt material developed for one medium for use in another medium.

4.6.2 Video Cassettes

A new system of physical distribution for television programs is emerging: cassette TV (225-232). Some of these systems are modeled upon the highly successful audio cassette developed by Philips. However, most firms seeking to enter the market have not observed the major means of Philips success (including Philips): compatibility. Thus, a proliferation of incompatible systems seems destined to compete with each other, as well as with established motion-picture, broadcasting, and cable television interests.

As shown in Table 11, videocassette/cartridge systems may be divided into three types according to the nature of the recording material:

Table 11: Video Cassette and Di

| Type | Recording Material, Manufacturer, & Trade Name | Probable Marketing Date | Recording Technology | Reproducing Technology | Picture Resolution, TV Lines | Audio | Expected Player Cost, Dollars | Ac Do |
|---|---|---|---|---|---|---|---|---|
| 1 | Magnetic Tape Cassettes | | helical-scan magnetic head (all) | helical-scan magnetic head (all) | ~250 (all) | | | |
| | Ampex/Toshiba (Toamco) Instavision | '71 | 1/2" tape[1] | | | 2 tracks | 800 | 10 40 |
| | Avco/Admiral Carti-vision | '71 | 1/2" tape[2] | | | 1 track | 450 | 8 10 |
| | Philips/Norelco VCR | '71 | 1/2" chromium dioxide tape | | | 2 tracks | 250-350 | 50 |
| | Sony VideoCassette | '71 | 3/4" chromium dioxide tape | | | 2 tracks | 350-450 | 50 60 |
| | Matsushita/Panasonic | --- | 3/4" tape | | | ------- | --- | -- |
| 2 | Silver-halide film | | | | | | | |
| | NordeMende Colorvision; Vidicord;etc. (Super-8 cartridge TV adapters) | '71 | optical | flying-spot scanner | 250 | magnetic stripe | 250? | 2 |
| | CBS/Motorola EVR (film cartridge) | '70 | eleciron-beam recorder[3] (8 3/4 mm film) | flying-spot scanner | 600[4] | 2 mag-netic stripes | 795 | po fi |
| 3 | Embossed Vinyl Plastic | | | | | | | |
| | RCA SelectaVision[10] (tape cartridge) | --- | multiple-beam holography | laser & vidicon | 250 | unknown | 400 | -- |
| | AEG-Telefunken/Teldec Video Disc | '72 | stylus recorder | pressure scanning | 250 | PPM in vertical interval | 125-300 | -- |

[1]compatible with EIAJ Type 1 (reel-to-reel) standard

[2]only records every third field

[3]records 2 fields in each frame

[4]limited to 320 lines by RF circuits in TV receiver (unless fed directly to monitor)

[5]60 minutes at half-speed extended play mode

[6]≤50 minutes for black-and-white

[7]TV cameras will be black-and-white initially

[8]including processing

[9]1/2-hour program

[10]RCA apparently will market an alternative system while working out SV problems ( ).

deo Cassette and Disc Recording/Reproducing Systems

| | Expected Player Cost, Dollars | Accessories[7] and Cost, Dollars | Cassette or Disc Playing Time, Min. | Unit Cost of Cassette or Disc, Dollars | Unit Rental Cost of Cassette, Dollars | Comments |
|---|---|---|---|---|---|---|
| cks | 800 | 1000, record/play<br>400, camera | 30[5] | 13, blank | ----- | camera has zoom lens and electronic viewer |
| ck | 450 | 850, inclu. TV set;<br>1000, inclu. TV & camera | ≤120 | 10-25, blank<br>8-25, prerecorded | 3, up | |
| cks | 250-350 | 500-600 record/play | ≤60 | 25, blank | ----- | independent tuner for recording; timer |
| cks | 350-450 | 500, record/play<br>600-650, inclu. camera | ≤100 | 25, blank | 2-5 (to record programs) | |
| --- | --- | ------- | ---- | ----- | ----- | |
| etic pe | 250? | 25-250 (home movie camera) | ≤30 | 40, blank[8] | ----- | |
| g- c oes | 795 | possible color-encoding film camera in future | ≤25[6] | 15-30 | ----- | |
| own | 400 | ------- | ≤60 | $10^{9}$-20 | ----- | black-and-white only demonstrated |
| in ical rval | 125-300 | ------- | 5 to 15 | 2.50-5.50 | ----- | black-and-white only demonstrated; recordings on one side of disc only |

1. Magnetic-tape cassettes, for both recording and playback of television of programs. Tape is erasable in contrast to
2. Film cartridge systems, for playback only; and
3. Embossed-vinyl tape or disc systems, for playback only.

The marketing of most videotape cassette systems seems destined to be concentrated upon the home. Although all cassette systems proposed will be color-compatible, and may be connected directly to home TV sets, most of them have inferior resolution to that obtainable with presently available half-inch color VTRs. However, the "home movie" potential of cassette recording, once low-cost color cameras become available, is a feature of great attractiveness.

For educational use, it is important to attain the best possible quality. As listed in the resolution column in Table 11, magnetic-tape cassette (type 1) systems, and the video disc (type 3) are capable of resolving only 250 "TV lines". This unfortunate misnomer actually refers to the horizontal resolution, which is a measure of detail within each TV line. Live TV and high-band quadruplex VTRs are capable of 400 "lines", and both low-band quadraplex and helical-scan VTRs are capable of 300 "lines" (233). Also, at least one of the magnetic-tape cassette systems skips fields, with effects which can only be detrimental to quality pictures.

The system likely to prove of the greatest utility for general educational applications--especially if high quality still-pictures are to be exhibited--is CBS' EVR, a type 2 system. Also, this is the only system so far on the market. Therefore, it will be described in greater detail than other systems.

Following EVR, type 3 systems--RCA's SelectaVision and AEG-Teldec's Video Disc--will be discussed. However, no further information will be given on magnetic-tape cassette (type 1) systems.

4.6.2.1 Super-8 Cartridge Television

Before discussing EVR in detail, it should be noted that another type 2 system--Super 8 motion-picture cartridges--can be adapted for TV use very economically. Several such systems have been announced, such as by NordeMende in Germany, Vidicord (234) in England, and by Abto, Inc., and GTE-Sylvania in the U. S. It seems certain that major Super-8 cartridge producers, such as Kodak and Bell & Howell, will follow suit. Previously, Sylvania pioneered in the recorded television consumer market with their "Color Slide Theater", a sound-slide television combination (235).

Although there are serious compatibility questions within the Super-8 field, particularly in relation to the type (optical or magnetic) and temporal displacement of the sound track relative to the film frame being projected, all Super 8 films are potentially capable of being used in any Super 8 projector, and a vast library of materials is being put in this format (236).

4.6.2.2 CBS' Electronic Video Recording

EVR, a type 2 system, will compete with traditional audio-visual media, as exemplified by films and filmstrips, as well as with commercial and educational television. EVR has the potential to unite these heretofore somewhat competitive systems into a single system, which should then become a more powerful force in the market.

EVR was invented by Dr. Peter Goldmark of CBS Laboratories,[237-239] who regards it as the visual equivalent of his previous A-V breakthrough, the LP record. However, there is a much closer contender for this title--the video disc--which is described in a later section. Prototype work on EVR was done for CBS in England, and Motorola has exclusive U.S. and Canadian licenses to manufacture EVR reproducing equipment, which they call "Teleplayers".

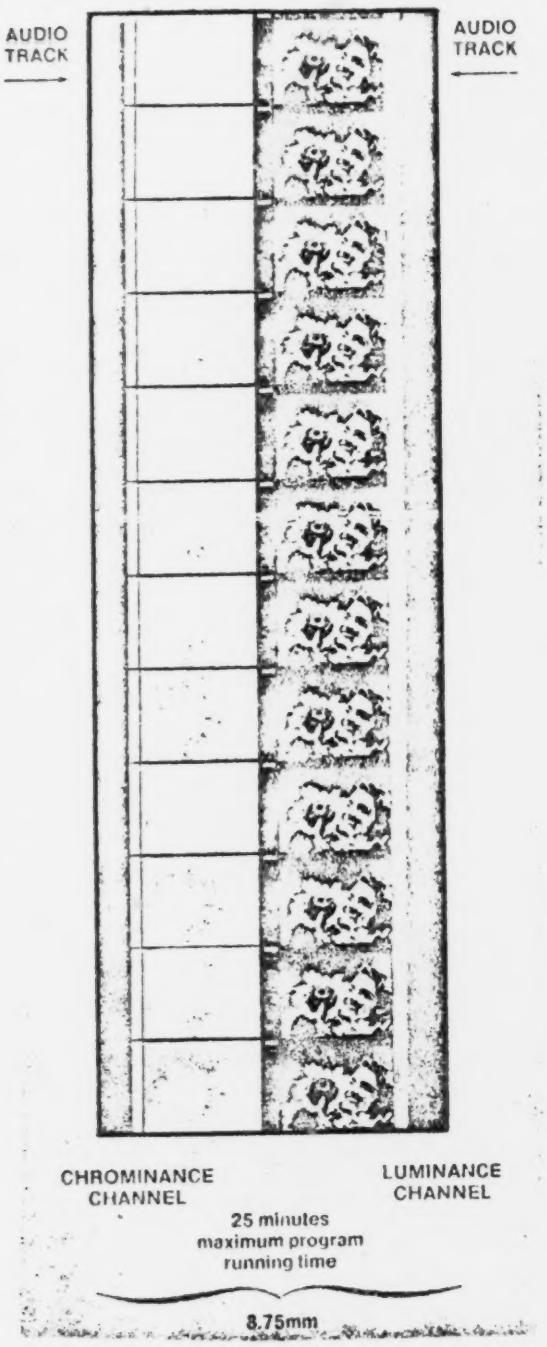
The English parentage of EVR is still apparent in the film, which is made by Ilford, Ltd., and in the program running time, 25 minutes per channel. The reason for this strange number is that EVR equipment was designed for half-hour programs in countries which use 50 Hz power; because we use 60 Hz, the running time is shortened by one-sixth here. In England, EVR will be marketed by a firm called "The EVR Partnership", which intends to give first priority to educational and industrial training markets.

EVR employs an entirely new format, which while totally incompatible with previous motion-picture film formats, also has some overriding advantages. It is made by slitting 40-mm film stock into four parts, each 8-3/4 mm wide. EVR film contains two complete audiovisual channels, side-by-side (see Figure 16). These channels can be used independently for black-and-white programs, or together for color EVR.

EVR probably represents one endpoint in the evolution of cartridge or cassette A-V, making use easy even for the most fumble-fingered. Kodak's Super-8 cartridges (for movies) and Instamatic cartridges (for still pictures) have given tremendous impetus to

## THE EVR FILM

Illustrated below, three times its actual size, is a segment of the color format on EVR Film. Its dual channels provide chrominance, or color information, on the left, and luminance, or picture information, on the right. There are two parallel sound tracks. A fully loaded color cartridge contains 25 minutes of uninterrupted color programming.




| | |
|---|---|
| **Capacity** | 750 feet of film, containing 90,000 individual luminance (picture) frames and 90,000 chrominance (color) frames. |
| **Size** | 7 inches in diameter, 2/3" thick. |
| **Weight** | Approximately 1 pound each, fully loaded. |
| **Composition** | Molded high-impact plastic. |
| **Compatibility** | Compatible and interchangeable with all licensed makes and models of EVR Players. |

OPERATION

| | |
|---|---|
| **Playing time** | 25 minutes maximum. |
| **Film speed** | 6 inches per second. |
| **Rewind time** | 1 minute for a fully-loaded cartridge. |
| **Threading** | Reel-to-reel with fully-automatic threading at start and automatic resealing of cartridge after rewind. |

EVR FILM

| | |
|---|---|
| **Type** | Safety. |
| **Width** | 8.75mm. |
| **Thickness** | 2-3, 4 mil. |
| **Perforations or Sprocket Holes** | None. |
| **Sound** | Dual magnetic sound tracks. |

GENERAL

| | |
|---|---|
| **Program Materials Acceptable** | 35mm color motion picture film.<br>16mm color motion picture film. |
| **Video performance** | Capable of providing resolution better than 500 lines horizontally. |
| **Audio performance** | Capable of providing 100 Hz to 10 kHz response ± 3 db. |
| **Scanning rate** | 525 lines, 60 frames. |
| **Synchronization** | Electronic, from optical mark. |

Specifications subject to change without notice.
For further technical information, contact the Technical Services Department of CBS Electronic Video Recording.

March 28, 1970

## PRICE INFORMATION

| QUANTITY | PROGRAM TIME IN MINUTES | | | | |
|---|---|---|---|---|---|
| | 5 min. | 10 min. | 15 min. | 20 min. | 25 min. |
| 50 | 9.00 | 15.90 | 22.80 | 29.60 | 36.50 |
| 75 | 8.00 | 13.50 | 19.10 | 24.80 | 30.30 |
| 100 | 7.20 | 12.30 | 17.30 | 22.20 | 27.20 |
| 125 | 6.90 | 11.60 | 16.20 | 20.90 | 25.40 |
| 150 | 6.60 | 11.00 | 15.50 | 19.80 | 24.20 |
| 175 | 6.50 | 10.70 | 14.90 | 19.10 | 23.30 |
| 200 | 6.30 | 10.40 | 14.60 | 18.60 | 22.70 |
| 250 | 6.20 | 10.10 | 14.00 | 17.90 | 21.80 |
| 400 | 5.90 | 9.60 | 13.20 | 16.80 | 20.40 |
| 500 | 5.80 | 9.30 | 12.90 | 16.40 | 19.80 |
| 750 | 5.70 | 9.20 | 12.50 | 15.90 | 19.40 |
| 1000 | 5.60 | 9.00 | 12.30 | 15.60 | 18.90 |
| 1500 | 5.50 | 8.90 | 12.20 | 15.50 | 18.60 |
| 2000 | 5.40 | 8.60 | 11.70 | 14.90 | 18.50 |

The EVR Color Cartridge provides a maximum of 25 minutes of program. Cartridge cost is based on the running time rounded up to the next 5-minute increment.

Prices shown are per cartridge, and include all costs of converting customer's material to EVR Cartridges.

*Prices may change without notice. No order is binding until accepted by the Electronic Video Recording Division.

is a Trade Mark of CBS Electronic Video Recording a Division of Columbia Broadcasting System, Inc.

Figure 16: EVR Color Cartridge Specifications and Pricing

amateur use of these media. Without easy loading, it will be increasingly hard to market older systems which require manual threading.

CBS and Motorola have speeded up the introduction of color EVR, so that their first customers will get a player with color capability at no increase over the originally announced price. The list price of a Motorola Teleplayer will be $795, which includes a one-year parts and 90-day service warranty. Motorola's Consumer Products Division will be able to handle servicing, because the electronics (based on Motorola's "Quasar" principle) uses 13 plug-in minicircuits. Teleplayers will also be available on a 3-year lease for approximately $28 a month, with option to purchase at the end of the 3 years. Renting for lesser periods is also a possibility.

How the EVR format works is best understood by reference to Figure16, where a compatible color/black-and-white format is shown. A major difference from conventional film is the complete absence of sprocket holes. EVR film does not have to go through the jittery and wear-producing process of coming to a complete stop at each frame, rapidly accelerating to the next frame, coming again to a complete stop, etc. Instead, EVR film moves at a completely constant and silent rate of 6 inches per second, equivalent to 60 frames a second. Also, the considerable proportion of material taken up by sprocket holes in small film formats is freed for image use. Film thickness is only 2-3/4 mils, or less than half of standard positive motion-picture film, which has a 1/2-mil emulsion on a 5-1/2-mil base. A 7-inch diameter cartridge can hold 750 ft. of film, which

contains 180,000 black-and-white picture frames and 2 magnetic sound tracks. Synchronization is by means of a timing mark between each pair of frames in the center of the film.

Black-and-white material is recorded on EVR film with two programs placed side by side. If these programs are completely independent, the second program is available only after the film has been completely rewound into the cartridge (which takes up to 2 minutes). However, in the case of color EVR, the right channel (channel B) contains only the luminance information, which corresponds to black and white intensity levels and to the green component of color TV. The left channel (channel A) is called the chrominance channel, and contains the rest of the information necessary to synthesize a full-color picture. Vertical bars, actually rows of fine dots, vary in spacing according to the color information in the signal.

A single flying-spot scanner is the light source for EVR reproduction. This scanning beam is split into two components, which are passed through the left and right film channels and directed to two photo-multipliers by light pipes. The sync signal is detected by a fiber optics system and converted into a synchronizing pulse. The information from all these sources is synthesized into a standard NTSC*color signal, and fed to the VHF antenna terminals of any TV set which has been tuned to either channel 3 or channel 4. Teleplayers are normally shipped pretuned (by crystal) to either channel 3 or 4, as the FCC allows only one of these channels in any area to be used for over-the-air broadcasting.

*National Television Systems Committee.

EVR partakes of all the good features of TV--while adding some of its own. Particularly important to educators are these:

1. no room darkening;
2. no screen needed;
3. all equipment can be placed in front of a room;
4. completely silent operation;
5. high-quality still-framing.

One of the great virtues of the EVR format--particularly in terms of flexibility for future use--is that although the two channels are tied together for color, in black-and-white they are completely independent. One channel can even be made partially dependent on the other. For example, EVR could be used for programmed instruction, where one channel contains the presentation or stimulus frames, and the other channel the response or reinforcement frames. EVR film is capable of being stopped at any single image, held for any length of time, and restarted at will, without any noise or picture degradation. This stopping and starting can be done either manually, or by pre-coded signals on the film itself. Thus, EVR is an ideal medium for programmed instruction. Another potential use of side-by-side frames is for true stereo television.

Furthermore, because the two sound tracks are also independent, each can contain voice information in a different language. An innovative educational application by Field Enterprises in Chicago puts preschool programs on one track, and related teacher-guidance information on the other.

This flexible format also lends itself to so-called "reference EVR", which uses sync marks to locate information in individual frames. In this case, EVR offers potential competition to conventional microfilm for the recording and retrieval of vast quantitites of information (see Table 10). It may be possible to use the two frames as one; that is, the conventional TV aspect ratio of 4:3 could be doubled to 4:6, and the resolution capabilities of the EVR recording medium thereby doubled. The only limitation here is in the monitor. Using a cartridge containing black-and-white images, it is possible to get much higher resolution by not converting the EVR signal to RF, but by feeding it directly into the video section. However, this would require receiver modifications on sets sold only for over-the-air reception. CBS claims that the RF signal is limited to 320 lines horizontally per channel, but the video signal (without carrier) has a capability of at least 500 horizontal lines. When multiplied by TV's 4:3 aspect ratio, this gives a capability in excess of 650 "picture elements" across one scanning line.

CBS has a laboratory in Nutley, New Jersey which will convert any of the following black-and-white or color media to EVR cartridges: 16-mm motion picture film; 35-mm motion picture film or slides; and one- or two-inch videotape. The heart of the conversion system is electron beam recording (EBR), using a 0.0001-inch diameter beam. This allows recording at a resolution of 200 lines per mm; the film which has a doped emulsion, has an inherent resolution of 800 lines per mm. After they have processed a large number of back orders,

they intend to attain a turnaround schedule from receipt to shipping of about 10 days, and ultimately, 5 working days.

Just as a distribution system, EVR is certain to make a large impression on the market. A single Teleplayer can drive up to 30 conventional television sets without additional amplification, or a Teleplayer can be placed at the head end of a community antenna or cable television system, thus providing potent competition for videotape--at least for playback use.

However, because the process of making the masters and copies is extremely complex, there is no competition with VTR or motion-picture film for making original programs. Also, distribution copies will be made only in quantities above 50, where the per copy cost is $15.90 for a 10-minute program. At 2000 copies, this drops almost in half, to $8.60 for a 10-minute program. Certainly, EVR is less expensive than 16-mm motion picture film for distribution. In runs of a thousand copies or more, the cost for a 10-minute EVR program would be only $9.00, competitive with Super-8.

Another important decision is to avoid the home consumer market for the present, and concentrate on industrial, education, and training markets. For this purpose, CBS is cooperating with a number of educational film producers. They have signed contracts with Bailey-Film Associates, the National Film Board of Canada, and the Great Plains Instructional Television Laboratory, and are currently negotiating with Encyclopedia Britannica Films, Coronet, McGraw-Hill, and Churchill. Undoubtedly, EVR will cut into the market for super-8 and 16-mm distribution prints, although it is not a present threat to 35-mm for large-audience screenings.

Also, because it can stop on a dime, and present an extremely bright, high-definition still picture, EVR may give severe competition to the old silent filmstrip format. However, one difficulty in competing with the sound filmstrip market is to keep the audio going while a still-picture is being shown. A separate audiotape playback system will be required for such use. However, should there appear to be reasonable market for this kind of thing, a spatially encoded sound system may be added (see Section 2.4.2).

If all program materials which have an expectation of repeated use over time were to be put into the EVR format, a great deal of transmission cost and complexity might be saved. For example, a bank of ten EVR Teleplayers could store the entire present stock of U. S. filmstrips. A fully loaded EVR cartridge contains 90,000 full color frames, or the equivalent of 3,000 full-color filmstrips. If methods can be developed to digitally encode and spatially store sound information compactly, 1,500 sound filmstrips could be kept in one EVR cartridge. There are 21,500 educational filmstrips available today in the U. S. (77)--the majority of which do not have sound accompaniment--out of perhaps a total 40,000 filmstrips, of which perhaps 6,000 have sound (73). Nine players could be put into a rapid search mode while one transmits information to the satellite system. In this manner, using one TVE (television-equivalent) channel, all the filmstrips in the bank could be broadcast in a total of four hours, and if necessary recycled throughout the day.

Requests for demand access would not necessarily have to be sent to transmitting locations. Using a printed directory (77),

users could select those filmstrips they wished to use the following day (or four-hour period, allowing for time-zone differences). Each filmstrip would have a unique order number, similar to the rapidly spreading use of ISBN's--International Standard Book Numbers (94)--in the book trade. These numbers would be keyed or otherwise stored locally in a small random-access memory device. When the still-pictures were broadcast, each sequence making up one program--or even particular stills of isolated interest--could be broadcast preceded by a digitally-encoded identification number, which would activate all receiving locations having the identical number prestored (see Section 2.4.4).

This process is analogous to jukebox systems which place selection mechanisms in a number of different locations. The central jukebox mechanism stores these keyed requests in an electromechanical memory, and plays the selections in the order of receipt. In the satellite system, everything happens much faster, and the selection mechanism must be random access--but the principal is the same. Some DAIRS (dial-access information retrieval systems) using video have random-access capability (163), but most tie up a program so that each use precludes other uses during the program time. In the satellite system, because each program can be transmitted at very fast rates, and accessed later at human-compatible rates by the use of electronic or electromechanical buffer systems, a much better over-all solution to the access problem may be achieved.

An analysis of the demand-access requirements for still-picture television programs has been made, and is given in Appendix 8.2.

4.6.2.3 RCA's SelectaVision

Of the proposed video cartridge systems, none is as technically innovative as SelectaVision (SV), developed by a team headed by William J. Hannan of RCA's Consumer Research Laboratory (240). SV utilizes phase holograms embossed on inexpensive vinyl tapes. A silent black-and-white system was demonstrated in the fall of 1969.

This experimental SV tape player incorporated a laser of 632.8-nanometers wavelength, with a power output of 2 milliwatts. The laser beam is passed through holograms embossed on half-inch wide 1-mil thick vinyl tape, running a 7-1/2 inches per second. The resulting image is picked up by a vidicon camera, and the video signal r-f modulated and transmitted to a conventional TV set through its antenna terminals. When the SV player comes to market,* it would sell for approximately $400, and cartridges containing half hour programs in full-color and with sound would be sold for less than $10 each. This is possible because the large-volume cost of vinyl tape material for a program of half-hour duration is expected to be only 15¢.

A five-step process is necessary to convert from 16-mm motion picture film to this tape. A color program is recorded on film by an electron beam recorder. This color-encoded master is developed, and converted by a laser to a series of holograms which are recorded as a positive photoresist on a Cronar tape base. Soft areas of the resist are washed away in a developing machine, the holograms appearing as

*However, according to lately received information, "RCA Corporation is...seeking an interim cartridge television system...until the bugs...can satisfactorily be ironed out." (241)

corrugations on the surface of the tape. A hologram master tape is then produced from the original photoresist hologram tape via a plating process, similar to that used in the production of phonograph records. Finally, copies to be marketed are manufactured on an embossing machine by rolling the vinyl tape and the nickel-plated master tape together under pressure.

An important characteristic of SV holographic recording is immunity from scratching, which is accomplished by using off-axis recording. This amounts to a form of spatial filtering, which separates noise due to scratches from the image. Also, the images will be speckle-free, as the SV holographic system uses multiple-beam recording, which creates a number of subholograms each of which is capable of reconstructing the entire image. If one or more of these subholograms is multilated, the entire image can be reconstructed without it. Furthermore, the Fraunhofer hologram technique used provides a unique image-immobilization characteristic, which enables an image to be always projected onto the TV camera regardless of the position of the tape. Thus, no shuttering or electronic synchronization between tape drive and camera scanning is needed. Furthermore, various types of movement can be achieved, including stop-motion without flicker, by changing the tape speed of the continuous-motion transport. The transport itself can have rather loose tolerances, because Fraunhofer holograms provide an in-focus image over such a depth that the camera-to-tape distance is not critical.

RCA may devote $50 million to the production of programs specifically designed for SelectaVision (242). These programs would be rented for from $3 to $5, rather than sold, and would initially

emphasize specialty interests, such as children's programs, cultural programs, theater, sports, and popular singers. Not until 1975 or 1976 would full-length motion pictures be added.

The RCA system is aimed directly at the home market. In the Variety article, no mention at all was made of the education market. Whether RCA's present marketing plans will persist is, of course, unknown. Even though the RCA system will be among the last of the video cassette systems to be marketed to the public, if they can maintain projected selling prices, their only competition will probably be the AEG-Teldec Videodisc system. RCA and AEG-Teldec are after the same markets, and how these markets will divide between the innovative holographic system and the technologically advanced extrapolation of long-playing record technology is not predictable.

4.6.2.4 AEG-Telefunken/Teldec's Video Disc

From an economic standpoint, the mass production of disc copies is so attractive that several electronics firms have tried to perfect a phonograph-based system for the playback of television programs. For example, Westinghouse prematurely demonstrated Phonovid, a still-picture TV system, in the mid-1960's (243). It used ordinary disc phonograph technology, but required an expensive scan converter to make the resulting signal compatible with home TV sets. In June 1970, AEG-Telefunken, and Teldec, a joint subsidiary of AEG and Decca of London, displayed a prototype full-motion TV disc system (244).

Video disc technology is a radical extension of the state-of-the-art of LP recording, with greatly increased groove density and rotational speed. Surprisingly, the original inventor of the LP record, Dr. Peter Goldmark, chose a serial medium--film--for CBS's

video playback system, EVR. Hill-and-dale recording with FM modulation is used by Teldec, rather than lateral recording, because side-to-side excursion of the grooves is the critical limiting factor.

For comparison, it may be noted that an ordinary LP record rotates at 33 1/3 rpm with a microgroove density of up to 250 lines per inch across the record. In the mid-1960's, a New Jersey firm, Wagner Research Company, advertised their Microdisc system, supposedly capable of 2,000-line-per-inch recording density, but it never came to market.

The Teldec system uses approximately 3,500 lines per inch, 15 times the groove density of LPs. Dr. Horst Redlich of Teldec has coined the expression "dense storage technology" to characterize the areal capability of the discs, claimed to be the highest ever attained--half a million bits per square millimeter, or 100 times that of LP records, and 500 times that of magnetic tape (245). Furthermore, Teldec records spin at a speed of 1800 rpm, 54 times that of LPs. Taken all together, the ultra-high groove density, the use of FM modulation, reduced signal amplitude, and short wavelengths are sufficient to record good quality TV pictures. The resolution and contrast of the presently developed black-and-white picture, and the quality of the sound are comparable to over-the-air reception.

Audio is recorded by pulse-position modulation (PPM) in the vertical interval--the short period between the vertical sync pulse and the commencement of the next frame.

An 8-inch video disc will hold up to 7 minutes of television program material, and a 12-inch disc, up to 15 minutes. When the

system reaches the market in 1972, full-color discs and color-compatible players will be available. The video disc player is expected to sell for between $150 and $250, with the higher-priced models incorporating an automatic disc changing mechanism capable of a less than 5-second change cycle. Repeat-action and still-picture modes will be available. Home players will generate an RF-modulated signal, so that they can be connected to an ordinary television set through its antenna terminals.

AEG/Teldec plan to turn out a half million pressings per hour, at a manufacturing cost of something less than $2.50 per hour-length recording, and claim that they can break even with a run of as little as a thousand copies of a particular program.

It would be surprising if no U. S. company were developing similar technology. MCA, a U. S. music distribution and promotion company, is rumored to be working on a "teledisk" system "superior" to AEG/Teldec's (246).

Taking as an over-all cost-effectiveness criterion the cost per hour of playing time, video disc technology should be in an extremely favorable competitive position compared to other television recording systems coming on the market.

## 4.7 EVALUATION OF ELECTRONIC VERSUS PHYSICAL DISTRIBUTION

### 4.7.1 Introduction

In this chapter, present and emerging technologies for the physical and electronic distribution of educational programs and materials have been surveyed. It has been shown that no one system or group of systems is likely to dominate the educational distribution channels of the future; rather, more diversity and individuality is expected.

However, it is possible to discern a trend in the direction of trading physical for electronic means for many types of messages and materials of relatively short length.

### 4.7.2 Interlibrary Loan Versus Facsimile

Most past studies of transportation versus communication trade-offs seem to have been concerned with the facsimile transmission of article or document pages as an alternative to interlibary loans. One would think that this should be a reasonably cost-effective substitute, because conventional interlibrary loans require that the loaned item be returned, thus entailing expenses to both the loaning and the borrowing libraries.

An analysis of electronic transmission for interlibrary loans was made by King about 1960 (247). For an average conventional loan, the lending library expended $0.62 and the borrowing library $1.20 in direct costs, or a total of $1.82. King estimated that direct costs for facsimile would be only $0.18 and $0.58, respectively, for a total of $0.76. He then proposed that the difference between the physical and electronic direct costs--$1.08--should determine the allowable expenditure for facsimile equipment and

maintenance and communication costs. In these calculations, he assumed that the average document to be transmitted by facsimile would consist of 10 pages. This is clearly much too low for books, and it must be assumed that King was considering facsimile service only for periodical articles.

If an average document is 10 pages, breakeven could be attained at an interlibrary distance of 50 miles, with a monthly volume of 500 documents per month. More significantly, a potential savings of $0.50 per document over conventional interlibrary loan costs could be realized at distances of about 10 miles, with volumes as low as 250 per month. In King's analysis, the most noticeable characteristic of facsimile economics is its sensitivity to volume. He found that distance becomes a minor factor when volume approaches 3000 documents a month, where costs drop close to $1 per document, or only 60% of conventional loan costs. This sensitivity may be attributed mainly to the high fixed costs of the terminal equipment.

Similar results, but much higher total costs, have been found in actual interlibrary facsimile tests (168,170). A particularly detailed but short experiment was done in 1967 by Schieber and Schoffner between the Berkeley and Davis campuses of the University of California (171). They found that an average request consisted of 14.2 pages, and cost about 90¢ per page, or $12.75 per request to transmit via Xerox LDX and a combined 90-mile Telpak A, cable, and microwave link (see Table 12). Of these costs, approximately one-half went for communications and associated equipment, one-third for LDX and associated terminal equipment, and only one-sixth for

Table 12: Costs of LDX-Telpak A Interlibrary Facsimile
(extracted from reference 171)

(376 requests fulfilled, totaling 5280 pages;
max. 99 pp/request; av. 14.2 pp/request)

| | Cost per Month |
|---|---|
| **LDX equipment and supplies** | |
| scanner | |
| installation[1] | $ 8.3 |
| rental, 1st 2500 cc | 550 |
| automatic document feeder, rental | 40 |
| printer | |
| installation[1] | 11 |
| rental, 1st 2500 cc | 650 |
| extra copy charges, 2800 @ $0.05 | 140 |
| Xerox 915, approx. 5000 cc @ $0.53/page[2] | 265 |
| Total equipment = | $1664.3 |
| **Communications** | |
| Series 8000[3] service, 90 mi. @ $15 | 1350 |
| Series 8000 modems | |
| installation[1], $18.75 x 2 | 37.5 |
| rental, $450 x 2 | 900 |
| microwave & cable installation[1] | 33.3 |
| Total communications = | $2320.8 |
| **Labor** @ 2.50/hour | |
| 534 req.[4] x 0.31 hr./request = 166 hr. | |
| +5280 pp x 0.04 hr./page = 211 hr. | |
| Total labor = $2.50 x 377 hr. = | $943 |
| Total cost = | $4928.1 |
| Cost per request fulfilled = $ 4928/376 = | $13.1 |
| Cost per page = $ 4928/5280 = | $ 0.93 |

[1]amortized over 36 months

[2]necessary intermediate to feed scanner

[3]formerly Telpak A (48 kHz channel)

[4]of these 534 requests, 376 were fulfilled via LDX document transmission, 106 were notifications of inability to fulfill via LDX, and 52 were serviced by non-LDX means.

labor. They concluded that manual procedures involved in interlibrary loans need to be reorganized before telefacsimile can be used effectively.

The California experiment had costs much higher than a going installation would experience, because the learning curve never approached its plateau. Also, they experienced nine LDX equipment or communication failures of an hour's duration or more during the month of operation, which amounted to one-sixth of the total time the system was in use. Even more damaging, average LDX utilization was only 35% of stated capacity. Also, they apportioned the costs of nonserviced requests--about 20% of serviced requests--to the system.

It is clear that a single scanner, communication link, and printer cannot provide reliable service, nor smooth out demand peaks to provide service times that customers expect at these costs. Actually, users indicated that they would be willing to pay 20¢ per page, but only if they could be assured of de very within a couple of hours, instead of the eight experienced d ing the trial.

A suitable degree of flexibility, and equipment and communication diversity could be achieved by using multiple office facsimile units and voice lines, even though these are of far lower theoretical capacity than LDX and Telpak A. For example, six Xerox Telecopiers could be placed at each location. Even though a Telecopier can transmit only one page every six minutes at 90-lpi resolution, multiple units could be operated so as to provide a continuous transmission capability of 40 to 50 pages per hour (see Table 9). This might equal

or exceed LDX throughput experience and provide two-way operation, at an equipment cost of $700 per month. This is about half the cost of one LDX scanner and printer, which can provide only one-way service.

Furthermore, half the cost of the LDX experiment went for communications. Telpak A provides the equivalent of 12 telephone voice channels for the price of 8, but six Telecopiers would need only half of Telpak A's capacity. Thus, cost savings of 20%, or $250 per month, could be realized on the line charges. Even more significant is that acoustic couplers can be employed instead of phone company modems in Telecopier operation. This feature alone could save $938 per month. Thus, the terminal expense required for LDX operation could be reduced by 100%. Also, in Telecopier operation, communication lines do not have to be leased. Thus, the switched telephone network could be used with some of the Telecopiers to increase operational flexibility and diversity.

Given the alternative of office facsimile equipment and ordinary telephone service, it seems that LDX and Telpak may have been unfortunate choices for this experiment. However, even though the cost of facsimile service could be reduced to about 50¢ per page with the arrangements outlined, this is still twice what users have stated they are willing to pay for the service (171). Could costs be reduced further?

The availability of facsimile channels on a communication satellite might reduce communications costs greatly, while adding the valuable features of multiple access and distance independence. Also, satellite-based facsimile provides a capability beyond that required

for interlibrary loan service, where it is unusual to expect that several recipients would want to receive the same documents at the same time. However, in public elementary and secondary education as presently practiced, it is likely that a great many schools would want the same printed material at a particular time. Thus, the cost basis per item received could be distributed over many users. This might reduce the cost per page below that of present in-school electrostatic copying, because facsimile receivers could be run unattended.

An interesting portion of Schieber and Shoffner's report is a section devoted to comparing telefacsimile to alternative indirect access means, such as mail or courier. Break-even formulas are provided (Table 13) which indicate that it may be better for a library to use an LDX link--expensive as it is--in place of acquiring an item, if the item is requested by a rush user less frequently than once in 30 years. Using a similar formula for conventional non-rush interlibrary loans yields a breakeven point of once every two years, using the values assumed in Table 13, where Z, the cost per conventional interlibrary loan, is taken to be $2. This means that it would be less expensive to own than to borrow non-urgently requested items only if they are accessed more frequently than biannually. And this is actually the situation with the bulk of material in large college and research libraries.

However, within the last decade, libraries acting as the main lenders in interlibrary loan transactions increasingly have stopped sending their originals* through the mails, or even by private

*Except for books and other lengthy items.

Table 13: Library Acquisition (Direct Access) versus Interlibrary Service (Indirect Access) Breakeven Formulas (after reference 171)

Library Acquisition Versus Rush Interlibrary (LDX) Service

$$X = \frac{Q\left(\frac{F + G}{K} + S\right)}{A}$$

where X = annual number of rush users of an item owned by a library

Q = annual number of rush requests fulfilled via LDX

F = initial acquisition cost of item owned by library

G = processing cost of item owned by library

K = life expectancy of item owned by library, in years

S = annual storage cost of item owned by library

A = annual cost of LDX-Telpak A service

Assuming Q = 2000, F = G = \$10, K = 40, S = \$0.5, and A = \$60,000, then X = 0.033 uses/year. This means that the library should purchase the item only if it expects more than one rush use every 30 years.

Library Acquisition Versus Any Type of Indirect Access (by mail or courier)

$$X = \frac{\frac{F + G}{K} + S}{Z}$$

where all variables are the same as before, except that X now represents non-rush users of an item owned by a library, and Z the cost per request via any indirect access method (mail, courier, facsimile, etc.)

Assuming Z = \$22 for courier via auto, $X = \frac{1}{22}$. This means that library should purchase item only if it expects more than one use every 22 years.

Of course, few if any acquisition librarians are prescient enough to be able to apply these formulas beforehand. However, they could very well be used in determining what items the library already owns should be transferred to a loan collection, such as the Center for Research Libraries.

courier. The rapid development of low-cost high-quality copying devices has made this possible. Therefore, comparisons today between physical and electronic document delivery should consider mailed nonreturnable electrostatic copies versus facsimile--not two-way mailing of original material.

This notion was carried to its logical extreme by Heilprin in his "D" (duplicating) library concept (248). Such a library would make copies of documents on-demand in preference to circulating them ("C"-library). Heilprin constructed this economic model during the early sixties, before electrostatic copying became dominant. He found that the total cost of a duplicated page depended mainly on the overall activity of a stored page (neglecting growth of the collection, and the cost of borrowing money). He calculated that the total cost per copied page would approach 4 cents as the number of copies duplicated approached the size of the collection, taken over an operating period of several years. He compared this to a library circulation cost in the range of from 25 to 50 cents per item, which is considerably lower than interlibrary loans, because the item does not have to be packed and mailed at either loan or return time. Averaging, it would appear that a library should only circulate items containing more than about nine pages per item, which is quite close to King's 10-page assumption.

On the other hand, physical delivery certainly retains the economic advantage when documents much longer than ten pages are to be transmitted. The most extreme case would be the delivery of an entire document collection, or "packaged library" to a remote location. As Simonds puts if :

"...consider a Boeing 707 jet freighter as a transmission channel. Assume that we wish to ship extensive library materials from New York City to Los Angeles. The cargo capacity of a 707 jet is 6,201 cubic feet. Let us load the plane with microfilm on which textual images have been recorded at a modest reduction ratio of 20:1. Assuming that each page of text contains 5000 alphameric characters, then, the plane would hold about $5.3 \times 10^{13}$ bits of information. If we assume an hour for loading and unloading, and a cruising speed of 550 to 600 miles per hour, the data-transfer rate (bandwidth of a sort) would be about 2.5 gigabits per second ($2.5 \times 10^{9}$ bits per second)!!

"For a TELPAK D channel to carry that much information would require about 20 months and would cost about $2,700,000. The cost of the 707 jet freighter by comparison would be about $10,000 and the total time of delivery would be about six hours.

"This example, though offered with tongue in cheek, illustrates that we must consider very carefully the desirability of designing a network of only electrical transmission facilities." (249)

However, Simonds has ignored such matters as how the 3-2/3 million volumes are put into microform. Allan Veaner of the Stanford University Libraries has estimated that it would take 150 man-years to microfilm each million volumes (250). At this rate, and assuming a cost of $5000/man-year, it would take 550 man years and cost $2.75 million to put this size library in microform. Simonds also neglects materials, processing, and packaging costs; the cost of reading devices and the inconvenience to the user of using microimages; the problems of getting copyright permission; and the problem of how 22 million microfiche are to be distributed to their ultimate users after the 707 has landed.

Also, Simonds does not state in what electronic form the library materials to be transmitted are in. This can make an extremely great

difference in the throughput rate over a communications channel. For example, if the materials are only available in print, facsimile would be the method of choice. Given a somewhat minimal resolution of 96 lines per inch, it would take about 3 minutes (180 seconds) to transmit one book page over the switched telephone network, or about three-fourths of a second over TELPAK D®. At the latter rate, 30 years would be required to transmit the 3-2/3 million volumes, compared to Simonds' estimate of 20 months. Thus, we must assume that the materials to be transmitted are already digitally encoded, and probably on high-density magnetic tape. This would entail a cost several times as great as the microfilming required for physical transmission, so it appears that Simonds is giving the benefit of the doubt to the communications side of the argument.

However, Simonds has assumed the use of Telpak D , an AT&T private-line service of 960 KHz bandwidth, equivalent to 240 voice channels. In interstate use, Telpak A, C, and D services have been replaced by Series 8000, 5700, and 5800 (there is no new equivalent to Telpak B). A new service, the Series 11000, is particularly favorable for the transmission of data, offering a rate of 230 kilobits per second for a price of $18 per mile per month (see Table 14). This is equivalent to 38.5 megabits per dollar (251), or almost twice the value of the old Telpak D service. This still leaves a 135 to 1 advantage with the 707, if costs of putting the information into microform or encoding it digitally are neglected.

However, a strong counter-case for communications can be made by choosing a much more cost effective communications medium than

Table 14: Selected AT&T Interci

| service designation | | | tarif | | fs (per month unless ot (half-duplex use basis[4] | |
|---|---|---|---|---|---|---|
| class | series[1] type | purpose | zone, miles | $/mile[5] | service terminal type | $/terminal |
| narrowband | | | | | | |
| 1000 | 1001 | remote metering, etc. | 1st 100 | 1.40 | | |
| | 1002, 1003 | TTY, radio telegraphy | next 150 | .98 | | 25 - 31.25 |
| | 1004 | FX TTY | next 250 | .56 | | |
| | 1005 | TTY, TTS, etc. | next 500 | .42 | | |
| | 1006 | TTY, FX TTY, etc. | ≥ 501 | .28 | | 13.75 add'l. |
| voiceband | | | | | send & receive | |
| 2000 | 2001 | voice | 1st 25 | 3.00 | | 12.50 |
| 3000 | 3002 | data | next 75 | 2.10 | 100 | 20 - 25 |
| 4000 | 4002 | Telephoto/voice[2] | next 150 | 1.50 | 202 | 40 - 50 |
| | | | next 250 | 1.05 | 201 | 75 |
| | | | ≥ 501 | 0.75 | 203[6] | 200 |
| 6000 | (6001 ) | audio transmission | | 4.00(1st day) | | 6.75 (1 day) |
| | (6002, 6003) | (for network | | 2.00 (each add'l. consec. day) | | |
| | 6004, 6005 | radio 6005 | | 18.00/mo. (max.) | | 90.00 (max.) |
| | (6006, 6007) | transmission) | | 10.00 (1st day) | | 12.00 (1 day |
| | 6008, 6009 | 6009 | | 3.00 (each add'l. consec. day) | | |
| | | | | 30.00/mo. (max.) | | 156.00 (max. |
| wideband | | | | | | |
| 8000 | 8800 | voice, data, fax (in any combination) | 1st 250 | 15.00 | 8803 | 425 |
| | | | next 250 | 10.50 | 8801 | 425 |
| | | | ≥ 501 | 7.50 | | |
| 5000 | 5700 | " | | 30.00 | 5703 | 425 |
| | | | | | 5701 | 425 |
| | | | | | 5751 | 650 |
| 11000 | 11048 | " | same tariffs a | | s type 8800 | |
| | 11240 | | | 18.00 | 11243 | 790 |
| | | | | | 11241 | 790 |
| | | | | | 11244 | 870 |
| 5000 | 5800 | " | | 85.00 | same tariffs as type 5700 | |
| 7000 | 7001 | TV interexchange channel[3] | | 12.10 (1st hour) | | 580 (1st ho |
| | | | | 4.40 (each add'l hour) | | 147 (each a hour) |
| | | | | 42.90 (8 consec. hours) | | 1,029 (8 co hour |
| | | | | 858 (8 consec hours, 20 day/mo.) | | 17,160(8 con 20 d |
| | 7004 | ETV(interexchange) | | 27.50 (1st channel)[8] | | [9] |
| | | | | 12.50 (2nd or 3rd)[8] | | |
| | | | | 10.00 (4th or 5th) | | |

[1] within any series and type, mileage charge is as stated, regardless of type of terminal used.

[2] for this service, add 33% to basic rate; terminals are $50 each

[3] for monthly service, same hour every day 7 days a week; occasional service: $0.55 per hour per airline mile and $26.25 per hour for each terminal

[4] for full-duplex use, add 10%

[5] airline mile basis

[6] also available in send-only, $100, and receive only, $175

[7] from Shannon-Hartley law, $C = B \log_2 (1+S/N)$, assuming $S/N = 25071$ or 24 db above message circuit noise, N

[8] color capabilit

[9] for each signa $40 for 1st ch also, channel location for t also, a distri plus $1.25 per

Selected AT&T Intercity Leased-Line Services and Tariffs, 1970

| fs (per month unless otherwise noted) (half-duplex use basis[4]) | | | analog capability | | digital capability | |
|---|---|---|---|---|---|---|
| service terminal type | $/terminal | typical monthly tariff (100 miles; 2 terminals) | voice-grade channels range | bandwidth | current, Kbits/sec. | theoretical, Kbits/sec.[7] |
| | 25 - 31.25 | 140 + 60 = $200 | portion of 1 | | ≤ 30 baud<br>≤ 55 baud<br>45 baud<br>≤ 75 baud<br>≤150 baud | |
| | 13.75 add'l. | 140 + 87.50= $228 | | | | |
| & receive | 12.50 | 22.50 + 25= $ 48 | | | | |
| 100 | 20 - 25 | 22.50 + 45= 69 | 1 | 4000 | 1.8 (FSK) | |
| 202 | 40 - 50 | 22.50 + 90= 113 | | | 2.4 (4-Ø PSK) | |
| 201 | 75 | 22.50 + 150= 172 | | | 2.4, 4.8, 7.2 | |
| 203[6] | 200 | 22.50 + 400= 423 | | | (VSB) 32 | |
| | 6.75 (1 day) | | | (300 - 2500) | | |
| | | | | (200 - 3500) | | |
| | 90.00 (max.) | 1800 + 180 = $1980 | | 100 - 5000 | | |
| | 12.00 (1 day) | | | (50 - 8000) | | |
| | | | | 50 - 15000 | | |
| | 156.00 (max.) | 3000 + 312 = 3312 | | | | |
| 8803 | 425 | 1500 + 850 = $2350 | 6 | 24 KHz | 19.2 | |
| 8801 | 425 | 1500 + 850 = $2350 | 12 | 48 KHz | 40.8, 50 | 384 |
| 5703 | 425 | 3000 + 850 = $3850 | 6 | 24 KHz | 19.2 | |
| 5701 | 425 | 3000 + 850 = 3850 | 12 | 48 KHz | 40.8, 50 | |
| 5751 | 650 | 3000 + 1300 = 4300 | 60 | 240 KHz | 230.4 | 1920 |
| s type 8800 | | 1500 + 850 = $2350 | 6 | 24 KHz | 19.2 | |
| 11243 | 790 | 1800 + 1580 = 3380 | 12 | 48 KHz | 40.8, 50 | |
| 11241 | 790 | 1800 + 1580 = 3380 | 60 | 240 KHz | 230.4 | 1920 |
| 11244 | 870 | 1800 + 1740 = 3540 | | | | |
| same tariffs as type 5700 | | 8500 + 850 = $9350 | up to 240 | ≤ 1 MHz | 230.4 | |
| | | 8500 + 1300 = 9800 | | | 500? | 7680 |
| | 580 (1st hour) | | 720 | 3 MHz video | | |
| | 147 (each add'l hour) | | | 5 KHz audio | | |
| | 1,029 (8 consec. hours) | | | | | |
| | 17,160(8 consec.hrs. 20 day/mo.) | 85000 + 17160 = $102960 | | | | |
| | 9 | 2750 + 63 = $2813 (minimum config.) | | | | |

[8] color capability available for 1st or 2nd channel at about 15% higher tariff

[9] for each signal source, channel input equipment is required, the tariff being $40 for 1st channel; 30 for 2nd; 25 each for 3rd and 4th; and 12.50 each for 5th & 6th; also, channel output equipment is required, the tariff being $7.50 per receiving location for the first output, and 5.00 per receiving location for the 2nd thru 6th; also, a distribution amplifier is required at each recieving location, at $15.00 plus $1.25 per outlet

Telpak or its equivalent--commercial television. The theoretical information-carrying capacity of any channel can be calculated from the Shannon-Hartley law (252):

$$C = B \log_2 (1 + S/N)$$

where C is the channel capacity in bits per second, B is the available channel bandwidth in Hz, and S and N are the powers of the signal and noise in the channel, respectively, in comparable units. If $B = 6 \times 10^6$, and S/N = 20000 to 1*, $C = 6 \times 10^6 \times \log_2(20000) = 8.4 \times 10^7$ bits per second. If S/N is only 2000 to 1*, $C = 6.6 \times 10^7$ bits per second. In an actual channel using today's technology, one would do very well to realize a third of this: $2.2 \times 10^7$ bits per second, or $8 \times 10^{10}$ bits per hour. Rounding off, one can say that a broadcast television channel has the capacity to transmit up to 80 gigabits per hour.

Assuming a program production cost of $50,000 for an hour's telecast, and a total audience of 10 million viewers, television can deliver and present the equivalent of 80 gigabits of information to <u>each</u> of 10 million individuals (a total of $8 \times 10^{17}$ hubits) at a cost of only $6.3 \times 10^{-11}$ cent per hubit!

The hubit, a unit invented by Richard Meier, is defined as follows: "A <u>hubit</u> is a bit of meaningful information received by a single human being.... According to classical informational theory, the receipt of this knowledge by an extra individual is redundant." However, Meier goes on to state that hubits measure

*Actually, S/N ratios are usually given in decibels. The Television Allocations Study Organization (TASO) has stated that a grade 1 (excellent) picture requires an S/N of 43 db, which is equivalent to about 20000 to 1; and that a grade 2 (fine) picture requires 33 db, or about 2000 to 1.

the values of messages to individuals in an interacting population, so that although the cultural record, or information "capital", is properly measured in bits, the per capita <u>flows</u> of these records should be measured in hubits (155, p. 131).

Using the hubit measure, communications is seen to compare much more favorably with the physical delivery of $5 \times 10^{13}$ bits to only <u>one</u> location. That is, comparing just production and transmission costs, the 707 delivers $5 \times 10^{13}$ bits in 6 hours for $5.5 \times 10^{-6}$ cent per bit, while television could deliver $8 \times 10^{17}$ hubits in 1 hour for $6.3 \times 10^{-11}$ cent per bit, or 16,000 times more information <u>per capita</u> at one ten-thousandth of the cost. Of course, without the hubit duplication factor of 10 million, air-lifted microfiche would carry 630 times as much information on a per-hourly basis, at a cost only 3% that of commercial television. However, as a rival to the 707, a much more valid comparison is with a point-to-point communications link, such as AT&T's Type 7001 television interchange channel service, which for occasional use, is only $1375 per hour for a 2500-mile hookup, or less than $5 \times 10^{-6}$ cents per bit (see Table 14, fn. 3). In any case, no useful purpose is served by comparing entertainment television with textual materials in microform -- nor by the type of comparison made by Simonds. It is easy to slant paper studies one way or the other by changing the assumptions, particularly when one system is put to a task for which it is inherently ill-fitted.

Returning to the simpler case of 10-page requests, and assuming that the lending library can absorb all copying, handling, and mailing costs at a charge of 10¢ per page (this would be a very

efficient operation), the cost which must be bettered by facsimile is not the interlibrary-loan direct costs ($1.82 in 1960, and probably close to $3 today), but only about $1.

However, there are few if any flat-bed scanners in use in libraries, even though such investigators as King have pointed out the critical importance of this device to cost-effective facsimile transmission for libraries. If the document page to be transmitted must be fed into a slot or wrapped around a drum, a copy must first be made of the original. Then facsimile costs must be added to those of electrostatic copying, except for postage. This makes facsimile for such use difficult to justify for all but the most urgent document requests.

Some types of flat-bed scanners are now available (see Table 9 ). One capable of transmitting a book opening (two facing pages) would certainly encourage libraries to make facsimile transmission the preferred mode of delivery for interlibrary requests between high-volume nearby points (1000 requests a month or more, and from 10 to 50 miles apart).

4.7.3 Circulation Versus Electronic Transmission of Educational Media

Surprisingly, the electronic transmission of nonprint media has not been given nearly as much attention as that of print via facsimile. However, an early but very detailed comparative study of the costs of providing auditory aids in the classroom by broadcasting, telephone, and phonograph records was done by Hogan and Wilmotte for the Committee on Scientific Aids to Learning (253). Cost surves were drawn for three cities: Baltimore, Denver, and Tulsa. To get an indication

of their results, the case for distributing 20 ten-minute programs per day to 160 Baltimore schools will be considered. The provision of phonographs and recorded programs would cost about $15,000 annually, while broadcasting or telephone hookups would be about three times more expensive. Other cases show similar ratios. This 1938 study concluded that over a range of daily program volumes from about 5 to the maximum possible, about 40 programs, the physical distribution of phonograph records to individual schools was far cheaper than any other method. Radio via commercial broadcasting was consistently two to three times as expensive. The use of school-owned UHF broadcasting stations or leased telephone lines was relatively volume-independent, but always at least twice the cost of phonographs and records.

The only extensive study found dealing with the use of television bandwidths for the transmission of a variety of educational media was an Office of Education funded feasibility study by Andereck et al. (158-160), which has been mentioned in Section 4.2.4. Andereck is head of a cooperative audiovisual service for the schools of the St. Louis suburban area. He found that during 1969-70, it cost the cooperative an average of $1.96 to circulate a 16-mm motion picture film, using a fleet of trucks (254). In 1965, the first phase of the North Circle Pilot Project, it was estimated that 4-channel ITFS equipment could be provided to one classroom in each of 200 schools for $21,000 per year. Assuming an equivalent personnel cost, total costs might reach $50,000 a year. If the system was used two-thirds of the time, or 16 hours a day, to distribute films in place of the

truck fleet, the cost apportionment to this service would be about $30,000. Assuming a school year of 200 days, this is only $150 per day. If films were transmitted "at speed", 40 to 50 twenty-minute programs could be sent per channel, or 150 to 200 using all channels, at a cost of $1.50 to 2.00 per film, competitive with the cost of truck circulation, which was $1.70 per item during 1964-65.

However, at that time, low-cost color videotape recorders were not available. Even today, the provision of 200 of them would probably bring the cost of the "television is a truck" system close to $100,000 a year, doubling per program cost to about $3 to $4 an item. Whether this added dollar or so expense per item is worth the convenience of electronic distribution must be decided by the schools which support the cooperative. However, again the long-term trends favor this development against the more labor intensive truck system.

In 1965, Sovereign wrote a thesis on "Comparative Cost of Instructional Television Distribution Systems" (255). Alternative systems considered were airborne television, with and without microwave relay; networks of UHF broadcast stations, by microwave relay and by videotape exchange; an ITFS network; and closed-circuit systems. For each of these distribution systems, one, two, four, and six channels of television were costed for both one-shift and two-shift operation. Costs for the preparation of the instructional materials themselves were not considered, nor were costs of terminal equipment such as television sets, individual antennas for these sets if needed, etc.

Results of this study showed that the lowest cost system was always an airborne broadcast station (i.e., MPATI), whose annual cost per square mile of ITV distribution for six channels was calculated to be $15.72. This was closely followed by an airborne broadcast station with microwave relay at $17.42.

Without the airborne capability, a big jump in cost was found. ITFS stations with microwave relays cost approximately $40 per square mile; and either ordinary UHF television broadcasting using a microwave network, or UHF broadcasting using a videotape network, cost over $50 per square mile annually for six channels. Under these same assumptions, closed-circuit costs totalled a huge $163. However, ITFS or closed-circuit costs should not increase appreciably with two-shift use.

Sovereign, continuing to work in the area of his thesis for General Learning Corporation, has completed an exhaustive study of the costs of various educational media systems (75, 256). This study indicates that satellite-based television has a lower per student cost than any of the above systems in covering a region equivalent to one-fifth of the United States, and serving ten million elementary and secondary students.

In conclusion, there is every indication that broadcasting has provided--and will continue to provide a cost-effective alternative to physical distribution for many types of printed and audiovisual materials. However, with a trend in the direction of more individualization in education, it remains to be seen whether this advantage can be maintained. In any case, over the longer term, the breakeven

point between electronic and physical transportation is expected to favor the former. Per-unit costs of electronics equipment continue to go down, and operation should become more and more automatic (257). In contrast to this--and despite large research and development efforts (258)--physical distribution will probably continue to increase in per-unit costs, if only because of its basically labor-intensive nature.

# 5. A SATELLITE-BASED MULTIPURPOSE EDUCATIONAL SERVICE

## 5.1 INTRODUCTION

In previous chapters, a variety of educational technology and communication media are described. This chapter outlines in qualitative terms how such media and technology might be utilized in a multipurpose educational satellite service.

In presenting the details of such a service, the basis which has been chosen is one full-motion television channel. This television-equivalent (TVE) bandwidth can accommodate a multiplicity of sub-channels for a variety of media, such as audio only, still-picture television, etc.

The concept of a TVE channel is used here only for a qualitative exploration of the use of media and technology in conjunction with an educational satellite. This study does not address the issue of what the quantitative telecommunications requirements might be to meet educational needs in the United States. Furthermore, it does not address the issue of how many TVE channels might be available from satellites designed primarily for commercial purposes. Plans for a number of such satellites have recently been filed with the Federal Communications Commission. These latter issues are under investigation by other researchers in the Washington University Satellite-Education Program.

## 5.2 SERVICE DESCRIPTION

Figure 17 depicts schematically a multipurpose educational satellite service.

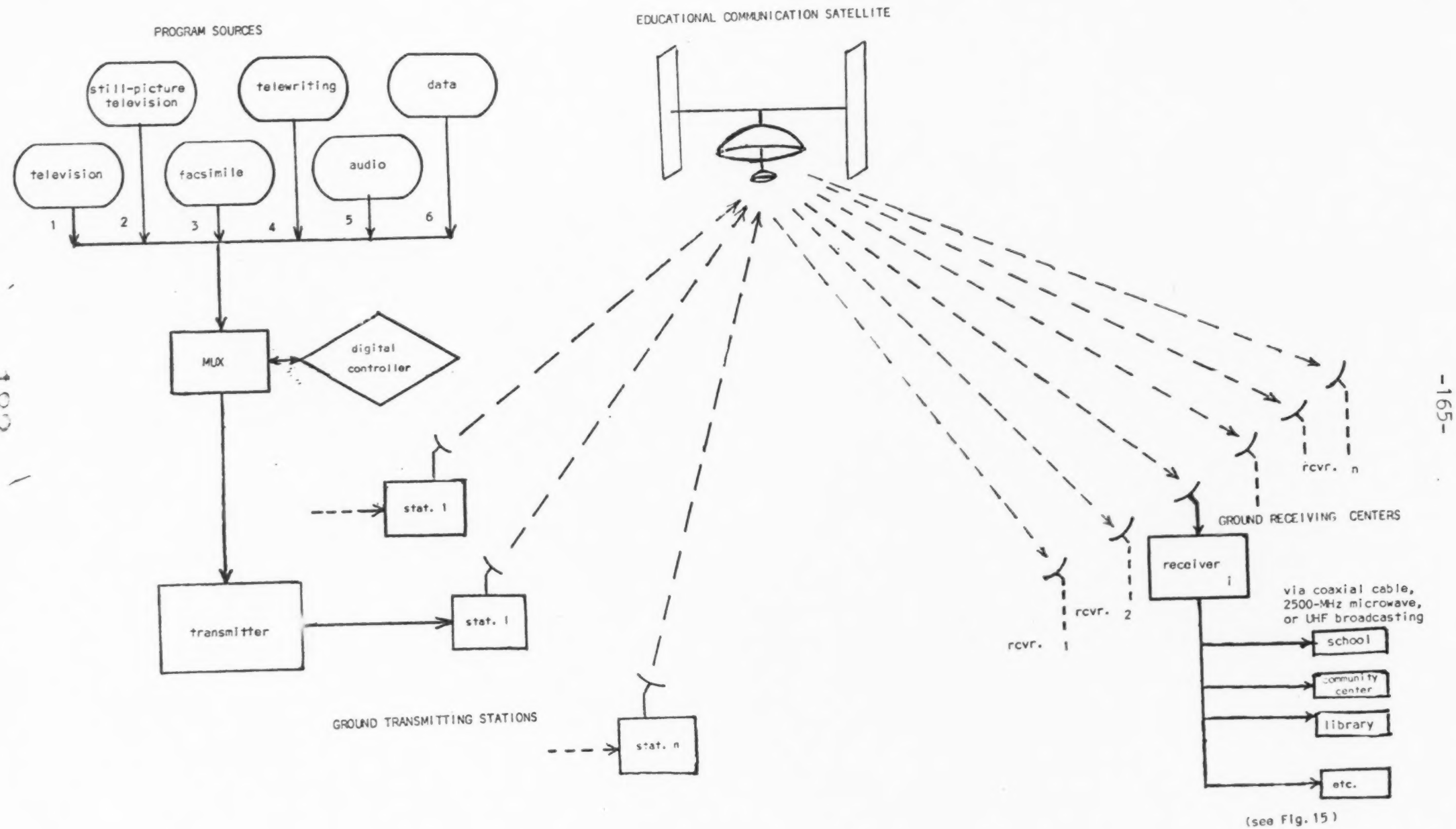



Figure 17: Multipurpose Educational Satellite Service

Six general types of educational program sources are shown:

1. Television, where the full repertory of sensory capabilities are needed for instruction. Included are live television, videotape, motion pictures, and such new forms as video cassettes and discs.
2. Still-picture television, where motion is not required. Included are sound filmstrips and live telelectures utilizing coordinated slide sequences.
3. Facsimile (still pictures or text) where neither motion nor sound is required. Included are slides, filmstrips, transparencies, and opaques in black-and-white, functional color, or full color.
4. Telewriting, where blackboard-quality drawings are sufficient for instruction, with or without accompanying live audio.
5. Audio, without accompanying pictorial or textual material. Included is live radio, audiotape, and phonograph records transmitting the spoken word, music, natural and artificial sounds, and combinations of these.
6. Data, which may represent encoded text, numerical quantities, instrument readings, or control signals. Included are telegraph messages (electronic mail), and data generated by or for computers such as data bases, calculated results, and programs.

Few if any ground transmitting stations are expected to have the capability to transmit all six types of program sources. However, if there is a variety of such types to be transmitted from one station,

particularly if there are priorities to their transmission, some form of automatic control is necessary to handle queues and to insure maximum TVE channel utilization. Control functions, as well as addressing, accounting, and simple reporting requirements may be performed by means of a small computer or special-purpose controller. Maximum utilization of the channel is aided by multiplexing the signals from various types of sources. The multiplexed signals are amplified and made to modulate an ultra- to super-high-frequency carrier. This composite signal is then relayed to the satellite from a directed antenna.

The satellite picks up the signals, which may be coming from a number of ground transmitting stations, and amplifies them. Some frequency conversion may also be done aboard the satellite to minimize interference with incoming signals. Then the signals are radiated towards the ground, where a large number of ground receiving centers store, process, and forward various types of signals for ground redistribution to schools, mobile classrooms, community centers, libraries, auditoriums, and the like.

For illustration, Figure 18 depicts a full-complement ground receiving center. However, it is not expected that any actual station would have every possible facility, and many may be capable of receiving and redistributing only a few of the many types of programs shown.

Some types of signals, such as telegraph messages, are addressed to particular recipients, while others are broadcast signals for general use. Selective receipt of broadcast programs is also possible, as discussed in Section 2.4.4.

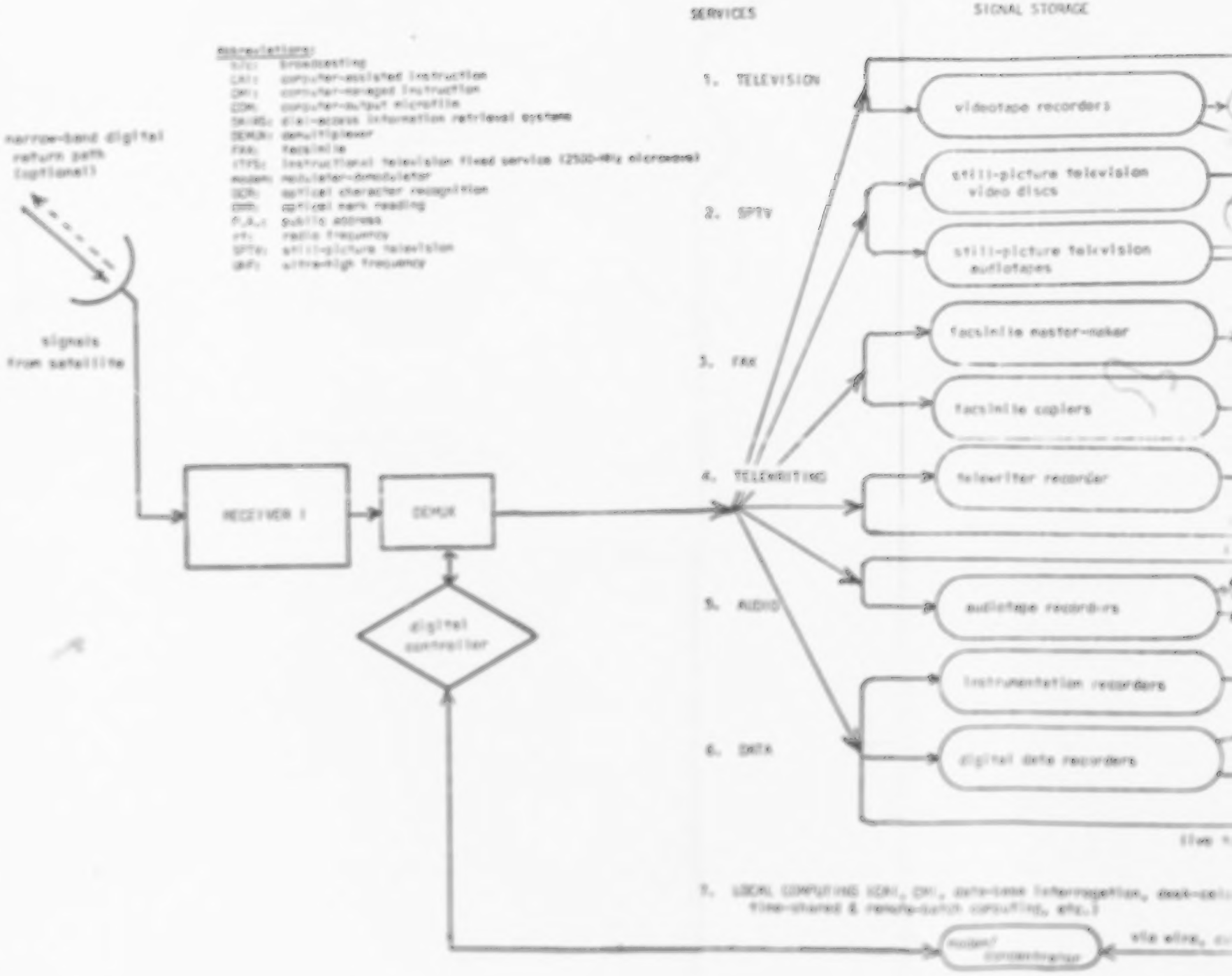
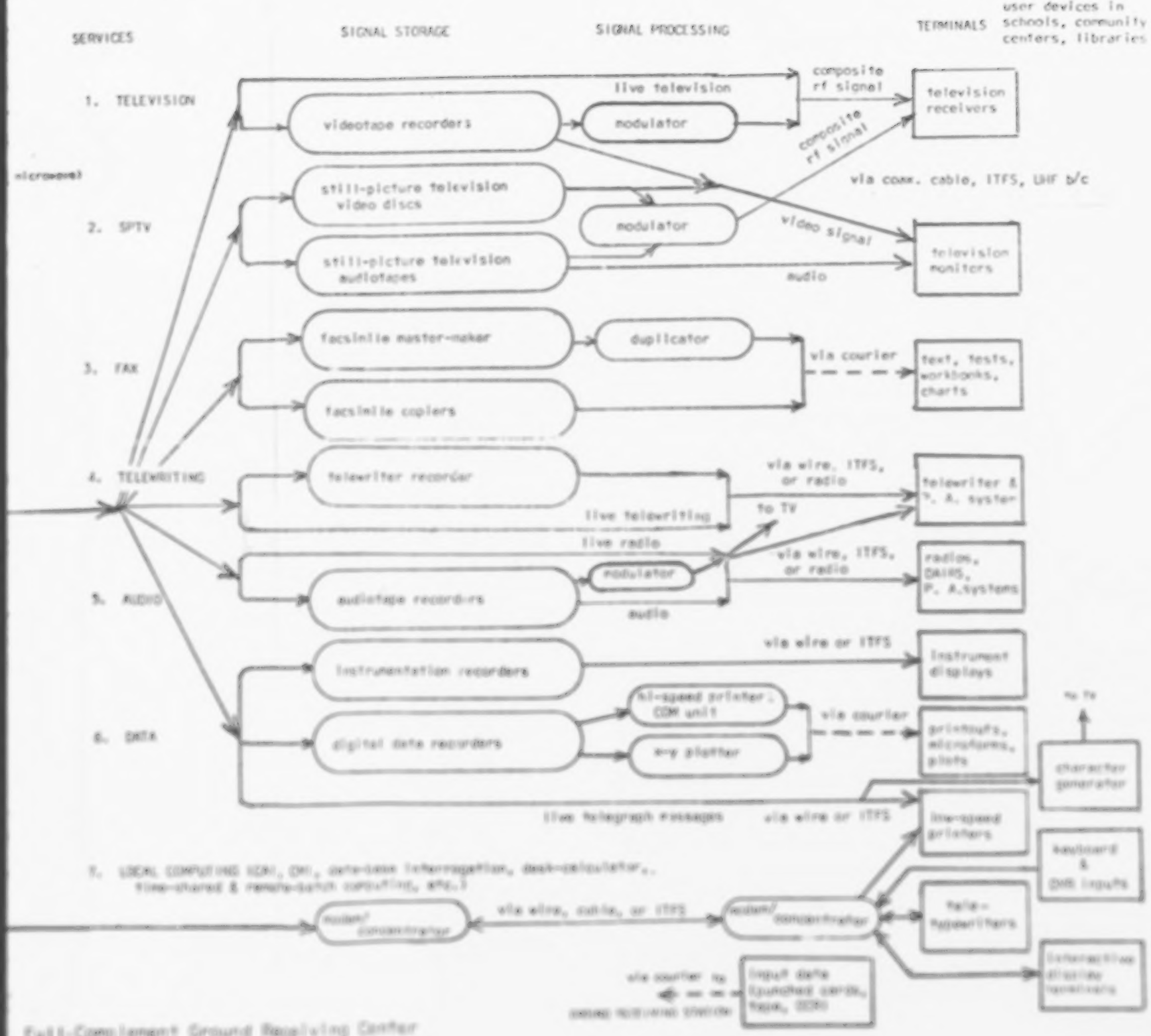



Figure 18: Full-Complement Ground Receiving Center




Full-Complement Ground Receiving Center

Signals from the satellite are picked up by a directed antenna, and amplified and demodulated in the receiver. Then the information-carrying signals are demultiplexed into their component types of program sources. A full-complement center must provide storage for each type of program, and also may provide certain types of processing. A minicomputer or special-purpose digital controller is used in this system to insure that the various types of signals are properly distributed to different storage devices, as well as to provide for local control and computational needs.

Again, there are six basic types of program reception storage facilities, corresponding to the six program sources. All of these have "live" bypasses except for still-picture television which requires buffer storage and conversion, and facsimile which is real-time but slow. Furthermore, because there is expected to be a considerable diversity of receiving devices in schools, community centers, etc., both closed-circuit and broadcast types of redistribution are shown for most program types. For example, if there is already a closed-circuit television system within a school which uses monitors as the display terminals, unmodulated video and audio may be delivered. On the other hand, if a school is set up to receive only over-the-air programs, stored television programs must be r-f modulated before they can be utilized by ordinary television receivers. However, it must be remembered that Figure 18 is highly schematic, and that unless a school is quite close to the receiving center ( a couple of miles at most), modulated video may be preferred, in which case a school having only monitors would have to use a demodulator locally.

Some types of programs may not be redistributed electronically, such as facsimile and voluminous digital data. In these cases, the expensive terminal equipment is centrally located, with resulting hard copy or microforms locally delivered by courier. However, telegraph messages ("electronic mail") usually are considered urgent, and are distributed electronically via wire or ITFS.

If the full-complement ground receiving center shown makes use of a general-purpose computer for the digital-controller function, and if it is of sufficient capacity, it may also be a source of shared computer power for local schools and other community educational facilities. Such functions as computer-assisted instruction (CAI), computer-managed instruction (CMI), data-base interrogation, desk calculator capability, and time-shared and remote-batch stored-program computing may all be accommodated, given the proper mix of central processing unit (CPU) capability, communication facilities, and terminal capabilities. Only a few of the many on-line and off-line modes of use are shown in the diagram. It should be noted that most interactive and computational functions are performed by the local CPU, and that no return path to the satellite is required. However, certain centers may have a modest transmitting capability to send control and accounting data to other centers, either via existing common-carrier links or satellite.

5.3 EVOLUTION OF THE SERVICE

At the first stage of development, only a few ground transmitters might be deployed. These might be best chosen from among existing educational media facilities, such as the National Information Center

for Educational Media (NICEM) and the National Center for Audio Tapes. Other centers, such as the Midwest Program on Airborne Television Instruction (MPATI), the National Instructional Television Center (NIT), and the Great Plains Instructional Television Laboratory, have built up large collections of videotaped instructional programs. The latter has recently added an electron-beam recorder for copying black-and-white videotapes onto 16-mm motion-picture film. This capability might be adapted for input to a satellite-based distribution service.

Each site could be provided with appropriate editing equipment to enable materials to be converted to a form suitable for satellite communications and storage. Also, considerable instructional material on films and videotapes might be edited in such a way that a sequence of still pictures could be drawn from the programs, and modified narrative developed to accompany it. Such "abridged" programs could be transmitted at a much faster rate than the full program and would find use for previewing and reviewing, as well as in their own right when the original program did not really require 100% full-motion capability.

At the end of the first year of satellite operation, three to five sites could be transmitting programs, with perhaps a hundred school systems and community centers on the receiving end. These initial receiving locations might be picked on a stratified random sample basis, to obtain the maximum amount of evaluation data. Some should be located in major metropolitan areas, some in small cities and towns, and some in rural and remote locations. The latter

require special attention, because operational personnel may be particularly hard to place in these remote areas.

To serve the greatest user population--and thereby spread the costs most widely--the eventual goal for an educational satellite would be coverage extending over all of North America. Sending channels might be assigned on a proportional basis, such as according to the number of school-age children in each country. However, each country should be assured of at least a minimum sending capability--perhaps two audio and one visual subchannel--regardless of their population, so that they actively participate.

Special efforts should be made to develop cooperative programs with our Canadian and Mexican neighbors. It would be difficult to exclude signals from border portions of these countries in any case, and an educational satellite with multichannel capability could stimulate cooperation, because both French and Spanish language material could be broadcast. This could provide advantages for U.S. foreign-language instruction.

## 5.4 APPORTIONING THE USE OF A TVE CHANNEL

In commercial TV practice, the broadcast day is from 6 a.m. to 1 a.m., leaving at least 5 hours unused. Let us suppose we broadcast 24 hours a day (see Table 15 ) and use a TV channel's bandwidth for non-TV purposes a third of the time--8 hours a day.

Assuming that a communications satellite is in orbit, the marginal cost of using it 24 hours a day, 7 days a week, is minimal. Of course, this would not be true if we had to employ ground personnel at all receiving stations 24 hours a day. However, many services

Table 15: Educational Satellite Service Schedule

(Assuming one TVE channel in operation 24 hours a day; the underlined program slots are for services alternative to full-motion television)

| | |
|---|---|
| Midnight - 6 a.m. | <u>Scheduled materials distribution</u><br>•Still pictures<br>•Facsimile<br>•Data } approximately 50 to 100 subchannels* |
| 6 - 8 a.m. | Adult ITV |
| 8 a.m. - noon | Live in-school ITV |
| noon - 1 p.m. | <u>Live telelectures</u><br>•teacher training<br>•interinstitutional communication } 50 to 100 telewriting, still-picture television and audio subchannels*<br><u>Telegraph messages and announcements</u> |
| 1 - 3 p.m. | Live in-school ITV |
| 3 - 4 p.m. | Live pre-school TV programs |
| 4 - 5 p.m. | Specialized adult programming<br>•vocational education and counseling<br>•consumer education |
| 6 - 10 p.m. | General adult programming<br>•public affairs and discussion |
| 10 - 11 p.m. | Specialized adult programming<br>•professional groups<br>•hobbiest groups |
| 11 p.m. - midnight | <u>Live interinstitutional communications</u>, 50 to 100 telewriting, still-picture television, and audio |

*The exact number of subchannels possible depends on the mix of services, and the technical factors discussed in Section 2.4.

other than real-time full-motion television can be stored for later access in unattended ground stations.

One possible schedule is given in Table 15. This example uses one TVE channel. As has been noted, one TVE channel can be used for the transmission of one full-motion color television program, or alternatively for transmitting a multiplicity of other programs which, taken together, require the same or less bandwidth.

In this schedule, two-thirds of a calendar day have been alloted to conventional ETV/ITV broadcasting. However, the remaining one-third of the day is devoted to alternative types of educational programs and services.

For example, in the midnight to 6 a.m. slot, various subchannels are devoted to scheduled materials distribution to school systems, such as still-picture television programs; facsimile transmission of documents, texts, and workbooks; and data-base and computer program transmission. As educators become more acquainted with the vast powers of the computer, they may find it useful to receive data bases and programs for use locally. For such purposes, time-multiplexed digital channels would be ideal.

From 6 to 8 a.m., adult ITV programming is broadcast, and [illegible] 8 a.m. until noon, live, in-school ITV.

However, from noon until 1 p.m., the TVE satellite channel is devoted to multichannel telelectures(152) for in-service training, inter-institutional communication (137, 151),etc. Many different telelectures may be broadcast simultaneously, accompanied in some cases by a variety of visual aids. Such a system is now in use at the University of Wisconsin for medical slide-lectures to remote

hospitals--up to 120 miles away. A single still-picture color television channel is made available via dedicated telephone lines (259).

This idea would be even more intriguing if some means of feedback could be provided (260). This might be done with Touch-Tone pads, if a simple response capability will serve. It is also possible that a reasonable gauge of audience reaction could be obtained by sampling those ground receiving centers which are capable of sending back a limited-bandwidth digital and/or voice signal via satellite.

From 1 to 3 p.m., more in-school ITV is broadcast; after the regular school day,preschool programs, such as the currently popular "Sesame Street" (261), would be aired from 3 to 4 p.m.

The time slot from 4 to 5 p.m. is used for specialized adult programming of particular interest to the housewife, such as consumer programs,and for vocational education and counseling. General-interest evening programming is aired from 6 to 10 p.m.

From 10 to 11 p.m., specialized adult programming is sent. This may differ totally in its projected audience from day to day. For example, one evening might be concentrated on items of interest to doctors, one on items of interest to lawyers on another, and so forth. Also, amateur or hobbiest interests can be served.

Finally, the slot from 11 p.m. to midnight is used for inter-institutional communications, using various mixes of still-television, telewriting, and audio-only channels. This material could be stored locally for access by the institutions the following day.

Instead of breaking down a single television channel into a multiplicity of channels, another way to utilize still pictures is

to employ FM radio channels. Each FM channel is 200 KHz wide, including guard bands. Using half this bandwidth, it would take about two seconds to transmit one television-quality still picture, theoretically. Subsidiary Communications Authority (SCA) is an FCC category for commercial use of subcarrier frequencies not used in FM stereo broadcasting, Musak being the best known example (262). Exhaustive histories of SCA are given in two theses (263, 264). Pictures sent by FM subcarrier could be stored at receiving locations to be accessed as wanted (265). At least one system of this sort is known to be in development by Educasting, Inc., (266) who term it "PictuRadio". Such a system could increase flexibility and economy, in that there would be no impetus to use more bandwidth than is needed at any particular time.

In both the TVE and the FME (FM equivalent) systems, receiving stations must have equipment capable of speed-buffering the picture signals, storing coordinated control and sound signals, and then sending these out later over open circuit, microwave, or cable links for reception on unmodified television receivers. Such options can greatly increase the flexibility of the television medium from the users' standpoint.

Eventually, demand access to materials may be provided, perhaps via "Touch-Tone" telephone terminal (267), so that each user can receive materials when and where he wants, use them, and once used, "forget" them. In such a system, there need be no bookkeeping, paperwork, or physical return. In Appendix 2, it is shown that

additional channels are not necessarily required to provide this degree of personalized service.

## 5.5 A SATELLITE-BASED CURRICULUM

What does a greatly expanded capacity to transmit live and stored messages all over the world mean to education? Satellite technology has the potential to change many aspects of our existence--and therefore our education, but we need to develop a whole new set of skills and attitudes to utilize this capability effectively.

Some examples from our present subject-oriented curriculum may serve to show this. One of the most obvious satellite-related subjects is geography. This generation is the first to have seen the world from the outside, and only this generation, perhaps, is comfortable with this global perspective. In the future, a teacher could choose from a library of recorded satellite views of the earth, or occasionally provide a highly dramatic and motivating live view of the earth. A high-resolution camera aboard a primarily communications-oriented satellite could provide this, or signals from existing weather and earth-resources satellites could be relayed to the educational communications satellite for broadcast to its receiving stations.

Other subjects which satellite technology may influence directly are mathematics and science. Solid geometry and spherical trigonometry are essential to describe the paths of space vehicles, and the exploration of outer space has entailed much basic research and the development of whole new technologies.

Less obvious is the impact of satellite technology upon the social sciences and the humanities. While from the far-off vantage point of a satellite, we cannot discern the microcosm of human activities directly--except for the most destructive--the very nature of a satellite as a truly international object must change our view of law, of language, of politics, and perhaps even of government.

Effects upon the arts are even less predictible, but satellites should enable all the world's peoples to share each others cultures on a day-to-day basis. While there have been so-called international art movements before, they will truly begin to live up to this billing only in the satellite era.

5.5.1 Sharing Intellectual Wealth

One of the most hopeful aspects of satellite technology is its ability to share the intellectual and educational wealth of the developed countries with the rest of the world. Vital intellectual resources, such as large research libraries, are almost completely lacking in the developing countries (190). As shown in Figure 19, there is only one million-volume library in all of Africa and only one in South America.

Again there is a trade-off to be made here between transportation and communication. No longer will scholars, scientists, and statesmen have to expend time and money for travel to exchange information. Rather, from their own communities, requests for information can go out over the satellite network. Acting as a truly global inter-library loan service, satellites can locate a library which has the

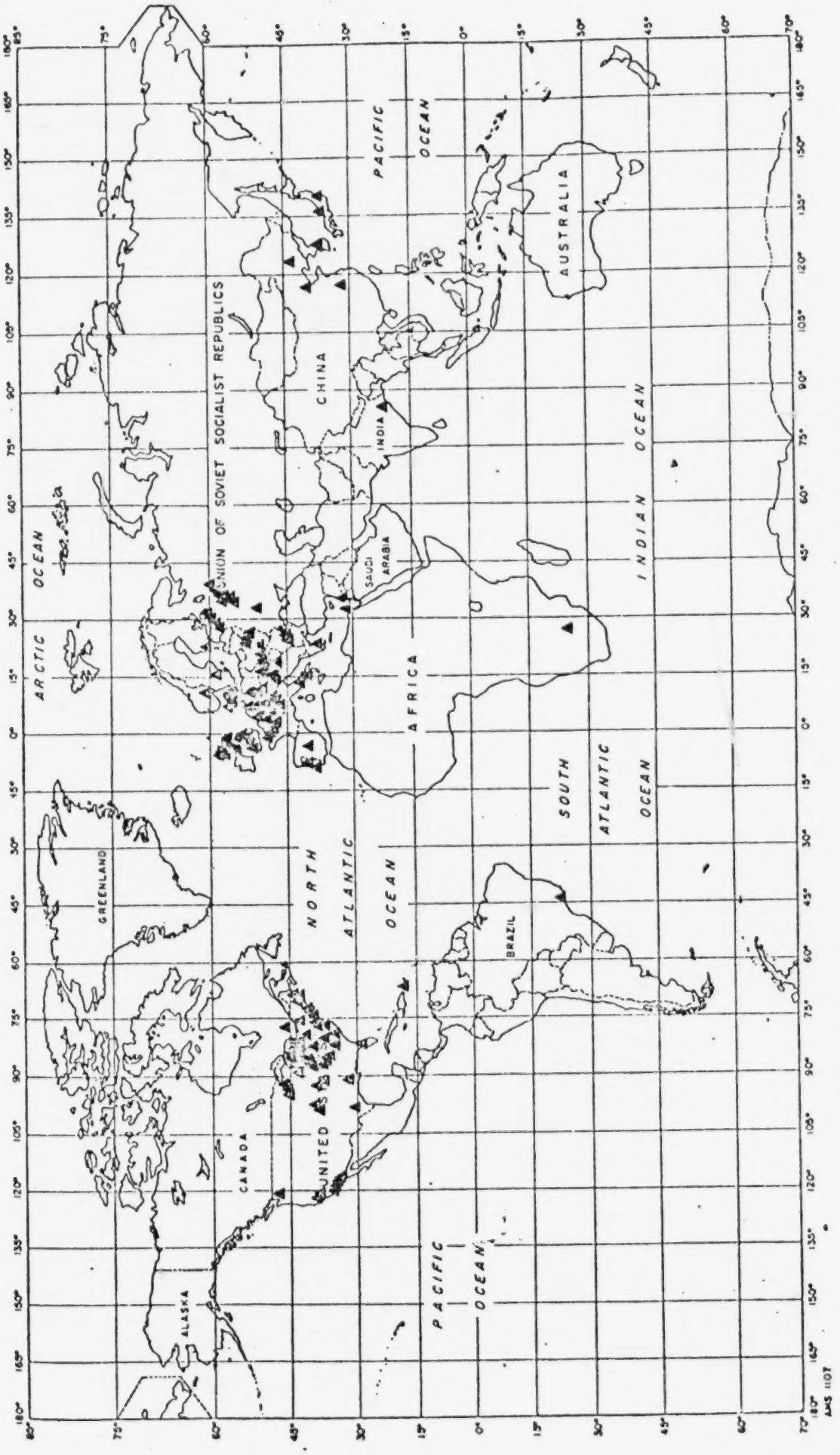



Figure 19: Million-Volume Libraries of the World (after reference 190)

information sought, and relay the desired information to the requester's location--in the time it takes today just to fill out the request.

Similar methods can be applied to instructional materials, but here, because we are dealing with entire populations, "people buffers" become even more important. Indeed, to use satellites effectively in education, or even just to distribute educational materials, we must have trained people on the ground. One of the first and most difficult tasks will be to "bootstrap" the development of such people in the third world.

One might think to get around this problem by allowing the greatest portion of these materials to be self-instructional, but self-instruction requires greater user sophistication than materials mediated by a trained person, particularly for beginning learners. The program writer cannot foresee all possible responses, and even were this possible, implementing such versatility would be prohibitive. Also, it may be essential for children to have grown up in an information-rich home environment--or to have experienced the equivalent in preschool activities outside the home or via television--before they can use self-instructional materials effectively.

Therefore, while the importance of programmed self-instruction is unquestioned for many purposes, overcoming initial hurdles of literacy and sensory-motor development will probably continue to demand those skills and talents that are unique to the human teacher.

A large part of today's learning experiences involve the cognitive and affective domains, but underutilize psychomotor skills. When we teach such arts as cookery and cosmetology, the tongue and the

nose become more important sensory inputs than the eye and the ear. However, these subjects cannot be taught properly without real-time and hands-on interaction with the subjects of instruction. Still more so, when our objective is primarily the acquisition of psychomotor skills, such as in painting, in playing music, in learning to drive, and to typewrite, we must obtain the actual "feel" of the situation.

Psychomotor experiences could be made available to learners initially by the use of simulators--but eventually they require access to "the real thing". Thus, it is of great importance to find out what parts of subjects are best taught by audiovisual methods, and what parts demand more compatible means.

Although a surprisingly large part of the academic curriculum may be presented by audiovisual techniques, a significant portion of vocational subjects cannot be learned by sight and sound alone. However, the proper combination of good audiovisuals with "hands on" manipulation may be the answer--and probably do it better, cheaper, and faster than by either method alone.

5.5.2 World-Wide Implications

Because a properly placed ring of satellites can "see" all parts of the world at once, we have greatly increased the possibility of trading transportation for communication. This idea was notably explored by Arthur C. Clarke in his book, "Profiles of the Future" (268). In a chapter entitled "World Without Distance", he discusses "teleportation", or instantaneous transport. While our present

understanding of natural laws does not permit teleportation of matter, it does for energy--or information.

As Clarke says,

> "What we...send is information--a description or plan which happens to be in the form of electrical waves--from which the original sights and sounds can be recreated."

Furthermore,

> "As communications improve, until all the senses--and not merely vision and hearing--can be projected anywhere on the face of the Earth, men will have less and less incentive to travel...Telecommunication and transportation are opposing forces."

So all-pervasive are the ramifications of this notion that it is difficult to separate out those matters in the communications versus transportation battle that are uniquely educational. For example, as we have seen, satellites can provide an "electronic mail" service. While this is not likely to change local service (i.e., within a single community), it can bring the world to every doorstep. Indeed, the total time from dropping "mail" into the satellite postal "box" until its delivery on the other side of the world should not take longer than to get today's physically embodied mail from one side of town to the other.

No one can foresee how such services will affect our way of life--nor our education. However, some things are certain to be changed. Perhaps the most important of these is language. More than any other form, satellite communication implies world communication, but a single human language for world communication would seem essential. Given the need,it is possible that an international auxiliary language, perhaps in pictorial form (269,270), may be used

for international communication via satellite, while retaining national languages for communication within each culture.

# 6. CONCLUSIONS AND RECOMMENDATIONS

## 6.1 INTRODUCTION

In this chapter, some conclusions will be drawn from the information gathered and analyzed in the main body of the report. These conclusions are arranged in an order similar to that of the major divisions of the report, with the following section headlings:

6.2 EDUCATIONAL TECHNOLOGY AND COMMUNICATION MEDIA

6.3 STILL-PICTURE TELEVISION

6.4 COMPUTER-ASSISTED INSTRUCTION

6.5 ELECTRONIC VERSUS PHYSICAL DISTRIBUTION

6.6 MULTIPURPOSE EDUCATIONAL SATELLITE SERVICE.

At the end of each of these sections, recommendations for further work are given.

## 6.2 EDUCATIONAL TECHNOLOGY AND COMMUNICATION MEDIA

Education today represents one of the largest public expenditure segments in the United States. During the 1969-70 school year, the educational share of the GNP rose to 7.5%, but the rate of growth of this segment is slowing down. In particular, the public is reluctant to increase their taxes further to support education, and increasingly is asking that schools be held accountable for the revenue they receive in terms of measurable student achievement.

Public elementary and secondary education is severely labor-intensive, with two-thirds of current expenditures going into instructional staff salaries. One possible way to make education less labor-intensive is to increase the utilization of technology

for instruction. However, the economic and social implications of any large-scale movement in this direction requires careful consideration.

With few exceptions, the introduction of instructional technology into U.S. schools has been uncoordinated, ineffective, and piecemeal. To become more effective, instructional technology must be established on an integrated, total-systems basis, with broad support from teachers, administrators, and the public, as well as long-term commitment from school boards.

Media diversity is essential if a wide variety of student characteristics and instructional situations are to be served in an economical manner. However, to utilize the wide variety of media available, an understanding of the characteristics and limitations of various media types on the part of educators is essential. In particular, media characteristics must be related to sensory capabilities. Also, as telecommunication facilities become available to educators, it is important to match their characteristics to those of the media to be transmitted. A comprehensive summary of educational media and their sensory capabilities has been developed and included in chart form for this study (see Figure 3 ).

By itself, the provision of an educational communications satellite is not likely to change any of the conditions and attitudes presently hindering the utilization of educational technology. These conditions and attitudes must be changed if communications satellites and other innovative technological developments are to find their way into the formal educational system beyond the token level. A great deal more attention must be given to the provision

of adequate and effective software for use in large-scale instructional systems than has been the case in the past.

It is recommended that actual experience with the use of experimental satellites, such as the ATS series, be made available to U. S. educators, so that the advantages and disadvantages of satellite-based educational services can be determined before widespread use is attempted. Experiments have been proposed for Alaska, the Western U. S., and the Pan-Pacific by H. Wigren of the National Education Association at a Conference on Educational Satellites at Nice, France, during May 1971.

It is also recommended that careful cost studies be made of various alternative methods of distributing instructional programming. If warranted, experimental work might then be initiated on promising methods of utilization of satellite-based channels, involving such media as still-picture television, facsimile, and data transmission in addition to conventional radio and television. Particular attention should be paid to the adaptability of many types of present media to satellite transmission.

6.3 STILL-PICTURE TELEVISION

Many learning situations do not require full television capability. Often, the use of still pictures plus sound--a kind of televised filmstrip--can serve instructional purposes as effectively as full-motion television, as shown in a number of experiments. Also, television uses up a greater portion of spectrum space than any other medium. Still-picture television techniques could provide many more programs in the bandwidth occupied by one full-motion television channel. Other potential advantages of the still-picture

television medium for instruction include a greater diversity of programs from which to draw, lower program production costs, and a relatively greater independence of picture and sound information.

Potential disadvantages include an increase in the cost and complexity of ground-station equipment, and possibly a higher signal-to-noise ratio than necessary in conventional television to overcome frozen noise. Studies have been made to determine the theoretical number of still-picture television programs which could be accommodated within one TVE channel using multiplexing techniques.

It is recommended that the still-picture television medium continue to be explored, with particular emphasis being given to determining the actual complement of equipment that may be needed for satellite-based transmission, and associated costs over and above those of full-motion television. Also, techniques of mitigating the effects of frozen noise, and of audio compression should be investigated.

## 6.4 COMPUTER-ASSISTED INSTRUCTION

To become a cost-effective learning technology, computer-assisted instruction expense and complexity must be reduced by an order of magnitude. One promising approach is to combine CAI with ITV, as proposed in the TICCET system. TICCET has evolved from a totally centralized system, using vast communications links to bring CAI to schools, to a highly decentralized system using dedicated in-school computers. Interactive graphic displays can enhance the capabilities of CAI, but again costs must drop an order of magnitude if these devices are to be used widely in schools.

It is recommended that the general area of satellite-based computer applications to education continue to be explored, with more attention being given to such areas as data-based interrogation, scheduling, accounting, and other management functions, in addition to CAI.

## 6.5 ELECTRONIC VERSUS PHYSICAL DISTRIBUTION

### 6.5.1 General

In general, whether electronic or physical distribution of educational materials is to be preferred depends upon a number of factors, such as the following per-message criteria: total allowable delivery time; total cost; reliability; security; number of addressees; fidelity; retainability; feedback requirements; and message priority. Nevertheless, it is possible to perceive an over-all trend towards the replacement of physical with electronic means of distribution for many types of messages.

### 6.5.2 Telephonic Communication Versus Postal Delivery

Postal volume, including all varieties of mail, is growing at a constant rate, while telephone call volume is growing at an increasing rate. Sometime during the 1930's, annual call volume exceeded annual pieces of mail handled, and by 1966 had grown to twice the mail volume. Meanwhile, the postal service, which formerly just about broke even, has incurred a steadily increasing deficit. In an effort to alleviate this situation, the running of the Post Office has been turned over to a quasi-public corporation. All classes of mail will now be expected to pay their own way within ten years. This decision should accelerate the tendency to trade

transportation for communication, because the cost to the user of physical delivery must increase sharply, while there is every reason to believe that communication costs will drop, as competition begins in the communications common-carrier industry, and with more alternatives such as communication satellites becoming available. In fact, if the Postal Service is to achieve its objectives, it may find it necessary to increase the use of communications media in its own operations.

6.5.3 Telephonic Communication Versus Broadcasting

Present distinctions between electronic communication systems intended for individualized message transmission and those designed for mass dissemination are expected to become less sharp. On one hand, the inauguration of Picturephone service and all-electronic switching will encourage the use of the switched telephone network for conferencing and other multiple address services. On the other hand, cable television will increase greatly the number of channels available to a community, thus providing greater possibilities for interaction and individualization of television--now the most important of the mass media.

6.5.4 Electronic Materials Distribution

The present largely physical distribution of print and nonprint materials for instruction and reference is expected to be challenged by electronic distribution. Films may be sent over television links and stored on videotapes; audio and video programs may be made available to a large number of remote locations via dial-access information retrieval systems; and printed materials may be disseminated rapidly via facsimile transmission.

6.5.5 Facsimile

For rapid delivery of printed materials, facsimile is the preferred technology. Although too expensive today for most educational requirements by an order of magnitude, satellite-based communications services could make it a useful alternative to physical distribution of educational materials in printed form, particularly in conjunction with microimaging and duplicating technologies.

6.5.6 Microimaging

Microforms are an attractive alternative to the physical distribution of full-sized hard copies of printed educational materials. They offer great compactness and lightness, low-cost, and ease of duplication. One of the most convenient forms for report dissemination is the microfiche, a sheet microform using linear reductions of about 20X. Recently, systems offering linear reductions an order of magnitude greater than microfiche have made their appearance. One of these "ultramicrofiche" can store an entire book, or in some cases, several volumes, at user costs less than a tenth of conventional publishing techniques. Even greater reductions are possible, but will require better access methods. A marriage of microfilm and computers (COM) offers speed and cost advantages of more than an order of magnitude over conventional text composition techniques. A marriage of microfilm with television could overcome problems of optically enlarging tiny images by providing the alternative of convenient reading of text on a television screen. The latter union is yet to be developed.

6.5.7 Picturephone and Cable Television

The displacement of physical transportation by electronic communications is expected to be boosted with the advent of Picturephone, which adds visual capability to the switched telephone network. Although primarily designed for face-to-face communication, because of its very wide bandwidth Picturephone service is expected to offer many types of man-machine interaction. For example, it may be a near-ideal terminal for computer-assisted instruction.

However, the resolution of Picturephone is quite limited, and for a high-quality full-color picture conventional television sets are necessary. When these sets are linked by means of coaxial cable to a central program source, the choice of programs is increased by from three to five times, and limited feedback from the audience become possible. Thus a great number of specialized programs and services may be provided.

6.5.8 Cassette and Disc Program Storage Systems

The development of the audio cassette has greatly expanded the uses of tape recording and reproduction. It offers a combination of convenience, compactness, low-cost, and versatility in the audio field that cannot be attained in any other way. One of its strongest features is the degree of compatibility achieved, so that any cassette can be recorded on any manufacturer's equipment, and played on any other manufacturer's equipment.

Video cassettes are now making their debut, and should become as convenient for sight and sound as the audio cassette is for sound alone. However, serious problems of incompatibility among the various

systems coming to market are likely, and the costs of both equipment and cassettes is likely to remain considerably higher, perhaps by an order of magnitude, than is the case with audio.

For educational use, a most promising technology appears to be electronic video recording, which essentially makes every television set a motion-picture display device. Also, it is the only video cassette system with inherently high-resolution capability, and referencible still-picture capability. However, copies of EVR programs must be made in complex centers, while magnetic-tape video cassette systems offer local and immediate recording capability and erasability. Also, from the cost standpoint, video discs are likely to attain the largest mass market of any of the video storage systems.

It is recommended that a thorough analysis be made of the relative trade-offs between electronic and physical distribution of educational materials. For example, the experience of two existing local media installations which exemplify these extremes should be evaluated and contrasted. Forest Park Community College has a relatively large-scale dial-access information retrieval system for audiotaped programs, which can be compared to a collection of audio cassettes used for a similar purpose at the University City High School. Both of these institutions are in Missouri.

Also, new curricula for elementary and secondary education designed to take better advantage of educational media technology should be considered. Such an effort might include an evaluation and listing of suitable existing program materials, no matter where they are presently located and no matter for what purpose they were

originally created. Also, further technological and economic studies are needed to aid in projecting trends in media utilization. In particular, the impact of new forms such as EVR on communications requirements needs to be evaluated.

## 6.6 MULTIPURPOSE EDUCATIONAL SATELLITE SERVICE

Given the equivalent of one or more satellite-based full-television channels, one can conceive of many different types of media and information services being provided to schools, community centers, and other public agencies. Although the full bandwidth of a television channel can be used for regular ITV on a real-time basis, it may also be used to carry such media as videotapes, films, filmstrips, telelectures, radio, facsimile, and data.

In addition to these satellite-based services, a full-complement ground receiving center could share its digital processing capability with local schools for such needs as CAI, CMI, data-base interrogation, desk-calculator computations, and time-shared and remote-batch stored-program computer use via wire, cable, or ITFS.

Satellite technology can add new and unique elements to existing curricula, bringing in the wide world beyond the classroom, and making possible the sharing of intellectual wealth on a world-wide basis.

In this report, some of the qualitative possibilities have been explored and a sample service schedule developed. Economic and technical studies are required to determine which possibilities are feasible. It is recommended that simulation and economic studies be done on the concept of a multipurpose educational satellite

service, leading to experiments between media centers and schools, possibly via a future NASA Applications Technology Satellite.

## 7. ACKNOWLEDGMENT

This work was supported in part by grant number Y/NGL-26-008-054 from the National Aeronautics and Space Administration, Office of University Affairs. This support is gratefully acknowledged.

Among those outside of the Washington University community who have helped with information, suggestions, or criticism are:

Mr. Paul Andereck, Cooperating School Districts of the St. Louis Suburban Area

Mr. Loyd Dorsett, Dorsett Educational Systems

Mr. W. R. Fall, MPATI, Inc.

Mr. Robert Glazier, St. Louis Educational Television Commission

Dr. Donald Lavianna, Westinghouse Learning Corporation

Dr. C. F. Nuthmann, MITRE Corporation

Messrs. Robert Hardester and John Riney, Southwestern Bell Telephone Co.

Dr. Kenneth J. Stettin, MITRE Corporation

Mr. Allen Veaner, Stanford University

Dr. David R. Wolf, Yerkes, Wolf Associates

# 8. APPENDICES

## APPENDIX 8.1 COMPATIBILITY PROBLEMS OF VISUAL MEDIA

Spatial media seem to have much more variable formats than temporal media. That is, visual media have greater diversity, and correspondingly greater compatibility problems than audio (see Figure 20). Some of the characteristics that may make adaptation difficult are: frame aspect ratios; the chain of devices employed in producing, transmitting, and reproducing material; and resolution and contrast.

It would be of great benefit if we could regard all media as potentially convertible into television. Unfortunately, commercial television may fall short of the quality needed for still-picture presentation, because its inherent characteristics are quite different. However, when the prime criterion is the success of a medium on its own terms, adhering to television's restrictions might hamper the exploitation of that medium's unique advantages. Certainly, programs originally made in Cinerama, and other extreme wide- and large-screen presentations make poor fare for TV.

In the following, some of the more important characteristics of visual media will be discussed, and an attempt will be made to suggest conversion or adaptation methods so that materials created for one medium may be used on another medium. Particular attention will be given to the problem of using various pictorial materials on television.

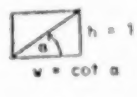
### 8.1.1 Aspect Ratio

One of the most obvious variables of visual media is the aspect ratio, which is the ratio of width to height (w/h) of the rectangular frame employed (see Figure 20). Such diverse media as overhead transparencies; 35-mm, 16-mm, and Super-8 motion pictures; television;

16-mm example

Frame dimensions are shown 3½x actual size. The dimensions given are those of the image on the film as determined by the camera aperture, in millimeters. The projector aperture reduces these by about 5% in each direction. (7.5 x 10.4)

Aspect ratios are the ratios of frame width (w) to frame height (h), or w/h. When normalized by letting h=1, w becomes equal to the cotangent of the angle between w and the frame diagonal. For example, in most film media and television, the aspect ratio is 4:3, which when normalized becomes 1.33:1, or the cotangent of 37°, approximately.




Relative resolutions are shown by the numbers in the circles. They represent the theoretical minimum film resolution, in line pairs per millimeter, which would have to be maintained in the projected film to fully utilize the theoretical resolution of broadcast television, which is approximately 480 scanning lines and roughly the equivalent along each scan line, or 230,000 black or white picture elements.

Relative frame areas are shown by the numbers in the squares. They represent the areas of the frames relative to that of the 16-mm film area taken as unity. [1]

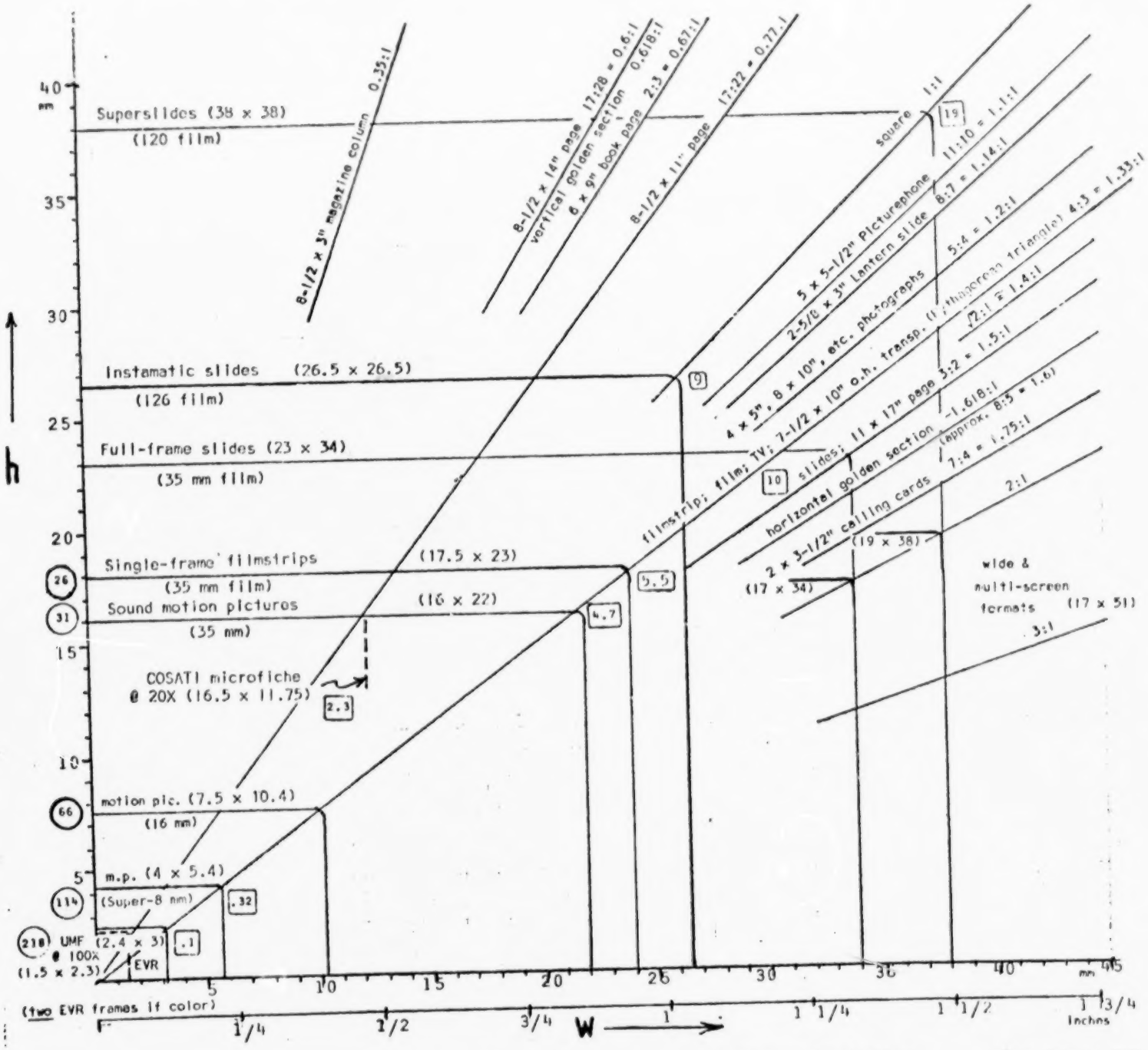

h
W
mm
Inches
Supersildes (38 x 38)
(120 film)
Instamatic slides (26.5 x 26.5)
(126 film)
Full-frame slides (23 x 34)
(35 mm film)
Single-frame filmstrips (17.5 x 23)
(35 mm film)
Sound motion pictures (16 x 22)
(35 mm)
COSATI microfiche
@ 20X (16.5 x 11.75)
motion pic. (7.5 x 10.4)
(16 mm)
m.p. (4 x 5.4)
(Super-8 mm)
UMF (2.4 x 3)
@ 100X
(1.5 x 2.3)
EVR
(two EVR frames if color)
8-1/2 x 3" magazine column 0.35:1
8-1/2 x 14" page 17:28 = 0.6:1
vertical golden section 0.618:1
6 x 9" book page 2:3 = 0.67:1
8-1/2 x 11" page 17:22 = 0.77:1
square 1:1
5 x 5-1/2" Picturephone 11:10 = 1.1:1
2-5/8 x 3" Lantern slide 8:7 = 1.14:1
4 x 5", 8 x 10", etc. photographs 5:4 = 1.2:1
7-1/2 x 10" o.h. transp. (½ thagorean triangle) 4:3 = 1.33:1
filmstrip; film; TV; 7:2 = 1.4:1
slides; 11 x 17" page 3:2 = 1.5:1
horizontal golden section 1.618:1
2 x 3-1/2" calling cards (approx. 8:5 = 1.6)
7:4 = 1.75:1
2:1
(19 x 38)
(17 x 34)
wide & multi-screen formats (17 x 51)
3:1
(c) H. Ohlman, 1971

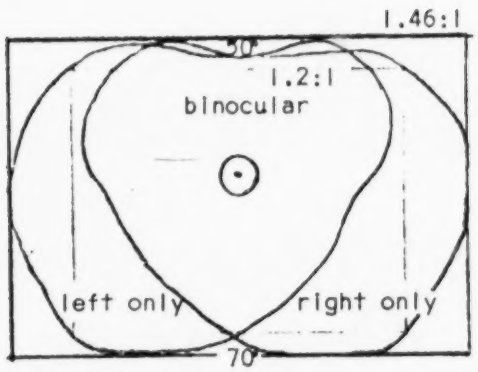
Figure 20: Comparison Chart of Print and AV Media Characteristics

and EVR all adhere to a 4:3 ratio. Equivalent aspect ratios of various media normalized to unit height are also given in Figure 20, so that comparisons among media formats can be made easily.

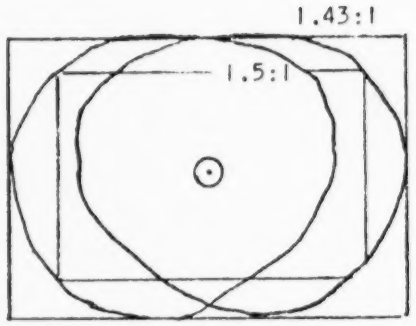
However, the vertical orientation of the printed page, with aspect ratios of 0.77:1 or less, is completely incompatible with nonprint media. It is interesting that 8-1/2 x 11-inch pages have an aspect ratio of 0.77:1, which is close to the reciprocal of the 4:3 (1.33:1 when normalized), ratio found in most projected media, and in television.

Curiously, few modern media exhibit as extreme an aspect ratio as the traditionally desirable "golden section", which is approximately 1.618:1. Full-frame 35-mm slides with a 3:2 (1.5:1) ratio come closest, although some wide- and multi-screen systems use 2:1, 3:1 or more. The golden section has had some use in the twentieth century. LeCorbusier used it (and the Fibonacci series) as the basis of his "modulor" (271). The golden section in aspect ratio terms is calculated from the proportion w/h = (w+h)/w, which works out to be the irrational number, $(\sqrt{5} + 1)/2$. It is sometimes erroneously given as 5:3, the ratio of two of the lowest adjacent Fibonnaci numbers. But if one uses higher terms in the series, a good approximation is possible. For example, 34:21 = 1.619..., is very close to the limit of the series, which is exactly that of the golden section. Even 8:5 = 1.6 does a reasonably good job.

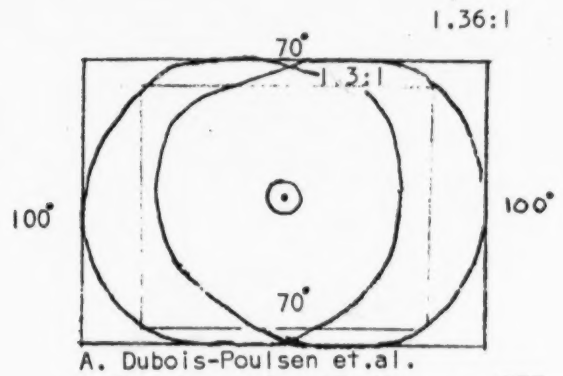
Why we seem to prefer a horizontal format in visual media, but not in print is not at all obvious. However, the binocular field of view of the human visual system has an aspect ratio extraordinarily close to the 4:3 of motion pictures and TV (see Figure 21). On the



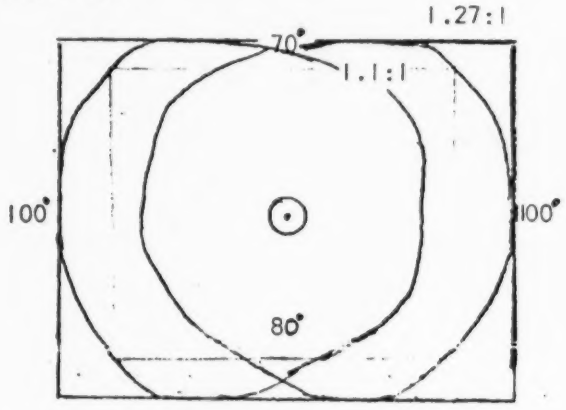

J. S. Wilentz
"The Senses of Man", Crowell. 1968
(each eye taken separately, and overlapped)




Schieck and Bruckner
"Kurzes Handbuch der Ophthalmologic",
1930-1932




A. Dubois-Poulsen et.al.
"Le champ visuel", Masson, 1952




W. S. Duke-Elder
"Textbook of Ophthalmology", Mosby, 1934

With eyes looking straight ahead, the symbol ⊙ indicates the center of the visual field. The numbers at the top, bottom, left and right of each rectangle indicate the extreme limits of the visual field from ⊙ in degrees.

Rectangles have been circumscribed and inscribed on each chart to determine aspect ratios, but inscribed dimensions are not exactly determinable.

The average aspect ratio of the four circumscribed rectangles is 1.38, and the average of the four inscribed rectangles is 1.28. The average of these averages is 1.33, identical to the aspect ratio of most projected media and television. Also, the separate averages of the circumscribed and inscribed ratios of the two most recent charts are both 1.33.

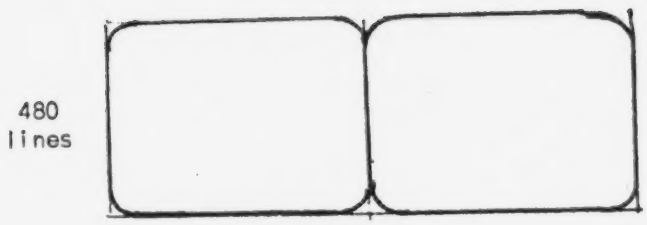
Figure 21: Aspect Ratios of Perimetric Charts Showing Binocular Field of View

other hand, it is rare to find horizontal page formats in the printed media. Perhaps one reason is that research on the visual apparatus during reading tasks seems to show the optimum line length or column width to be about three inches (272)--but with column lengths as long as practicable. Hence, multiple column formats in magazines and newspapers may have aspect ratios of 0.35:1 or less.

There are ways of coping with widely different aspect ratios in adapting materials for television transmission. Although the 4:3 ratio is fixed by the mask over the cathode-ray tube in every TV set, the television format could be regarded as a module in a "Multivideo" or "Multivision" combination (Figure 22). In this way, wide-, narrow- and multi-screen (273) formats can be obtained economically. To coin individual names for the formats shown, the designations "Twinvision", "Videotext", and "Quadvision", may be appropriate. In each case, not only is the aspect ratio altered, but the apparent resolution increased accordingly. Such techniques could be particularly appropriate for still-picture television, because over-all bandwidth savings are so great that halving or quartering them is insignificant. Bogatov, a Russian space scientist, has also suggested the wide-screen television idea (274).

8.1.2 Chain Effects

Even when a visual medium has an identical aspect ratio to that of television, it suffers a progressive loss of image area as it proceeds through all or part of the long chain: original--camera--optical printer--projector--TV camera--transmitter electronics--receiver electronics--receiver CRT tube (275). At the studio,

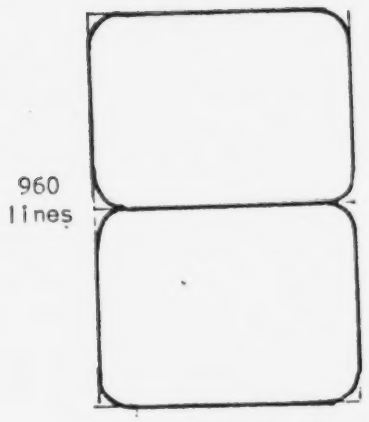



-600 "lines"

"Twinvision"

8:3=2.7:1

For wide- or multi-screen presentations, or for comparison between two image sources.

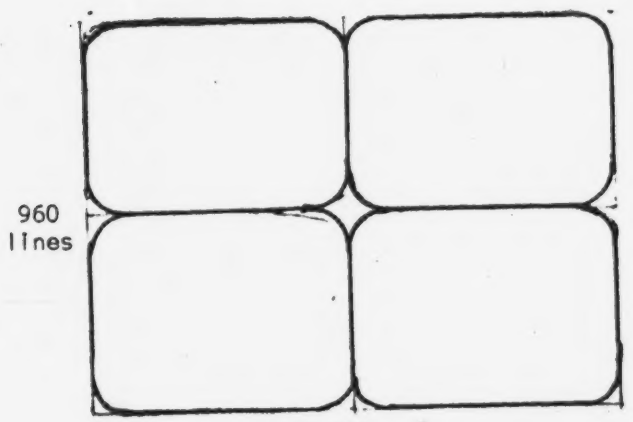



300 "lines"

"Textvision"

4:6=0.67:1

This aspect ratio identical with that of a book page.




600 "lines"

"Quadvision"

(4:3) x 4=4:3

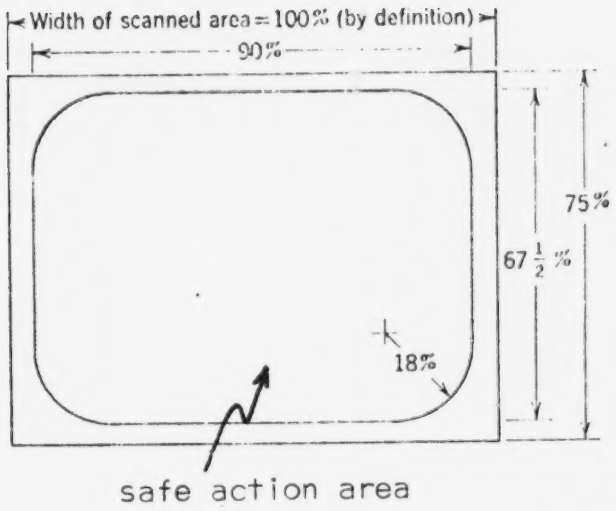
Quadrants may be used as a single large frame of high resolution, or independently for comparisons, stimulus and alternate response frames, etc.

Figure 22: "Multivision" Formats and Their Aspect Ratios

necessary adjustments of sweep and linearity controls change the picture area actually broadcast. In the home, maladjustment of sweep controls may excessively enlarge the image, entailing additional loss. Furthermore, the television image is not really rectangular, but employs rounded corners unlike any other medium, giving it a distinctive shape: ● . When all these losses are added together, it should not be surprising that the safety mask used in TV-camera finders is 16% smaller in height and 26% smaller in width than that of a similar film camera--a loss of 37.5% in the total picture area! If still-pictures are to be used on television, it is necessary to employ a similar mask in still cameras (see Figure23 ).

8.1.3 Resolution and Contrast

Theoretically, television and film resolution are incomparable, because the television picture, regardless of screen size, is composed of 480 usable horizontal scanning lines. Although 525 lines are transmitted, only 480 are used to form the picture. Therefore, the equivalent horizontal resolution, which is given in "TV lines", should be 480. Across the entire width of the picture, this is multiplied by 4/3 to give 640 "lines". However, home television receivers exhibit a horizontal resolution of only about 300 "TV lines", or 2/3 of the theoretical horizontal resolution. This is primarily caused by bandwidth limitations in the video signal when broadcast over a 4.2 MHz bandwidth. Each line is scanned in 63.5 microseconds, so maximum horizontal resolution is $4.2 \times 10^{6} \times 63.5 \times 10^{-6} = 267$ cycles, or "TV lines". Unless this bandwidth is increased, every other field would have to be repeated to get enough bandwidth to equate horizontal with vertical capability.



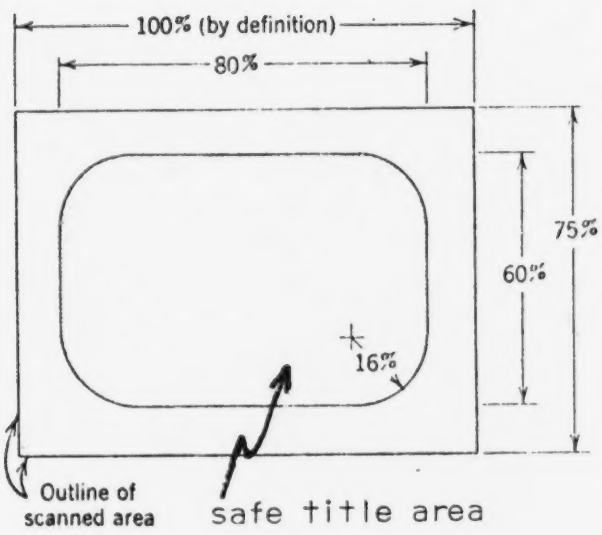




Figure 23: SMPTE Safe Action and Safe Title Areas for Television Transmission (after reference 276)

One can make a rough comparison with film by assuming that all 480 visible scanning lines must be reproducible (see circles on Figure 20). For example, only 26 lines per mm would be needed for filmstrips, and silver-halide film materials in common use can resolve this easily (see Figure 24). However, in 16-mm motion pictures, the theoretical resolution requirement would be 66 lines per mm at the projector aperture. From Figure 24, it would appear that only the black-and-white material could be used. However, the lowering of resolution of 16-mm color film is also found in color television practice, and observers of 16-mm color motion pictures sent over television cannot distinguish the quality from 35-mm film.

Super-8 film, unless specially manufactured for TV, would seem to fall far below the required resolution. However, in one experiment, in which Super-8 was projected over a film chain for television, qualified observers could not detect any difference from 16-mm quality.

When one gets down to EVR frame size, the resolution requirement is severe. But EVR masters are made on film with an inherent resolution of 800 lines per mm, which is considerably greater than most commercially available microfilm!

Film resolution figures by themselves may be very misleading, because resolution and contrast are interdependent. It is much better to use the modulation transfer function (MTF), as shown in Figure 24. Although contrast is not directly readable from these curves, it may be seen that at a low contrast (1.6:1), Ektachrome is capable of resolving only 35 cycles per mm, but at more normal contrast ratios, it may approach 50.

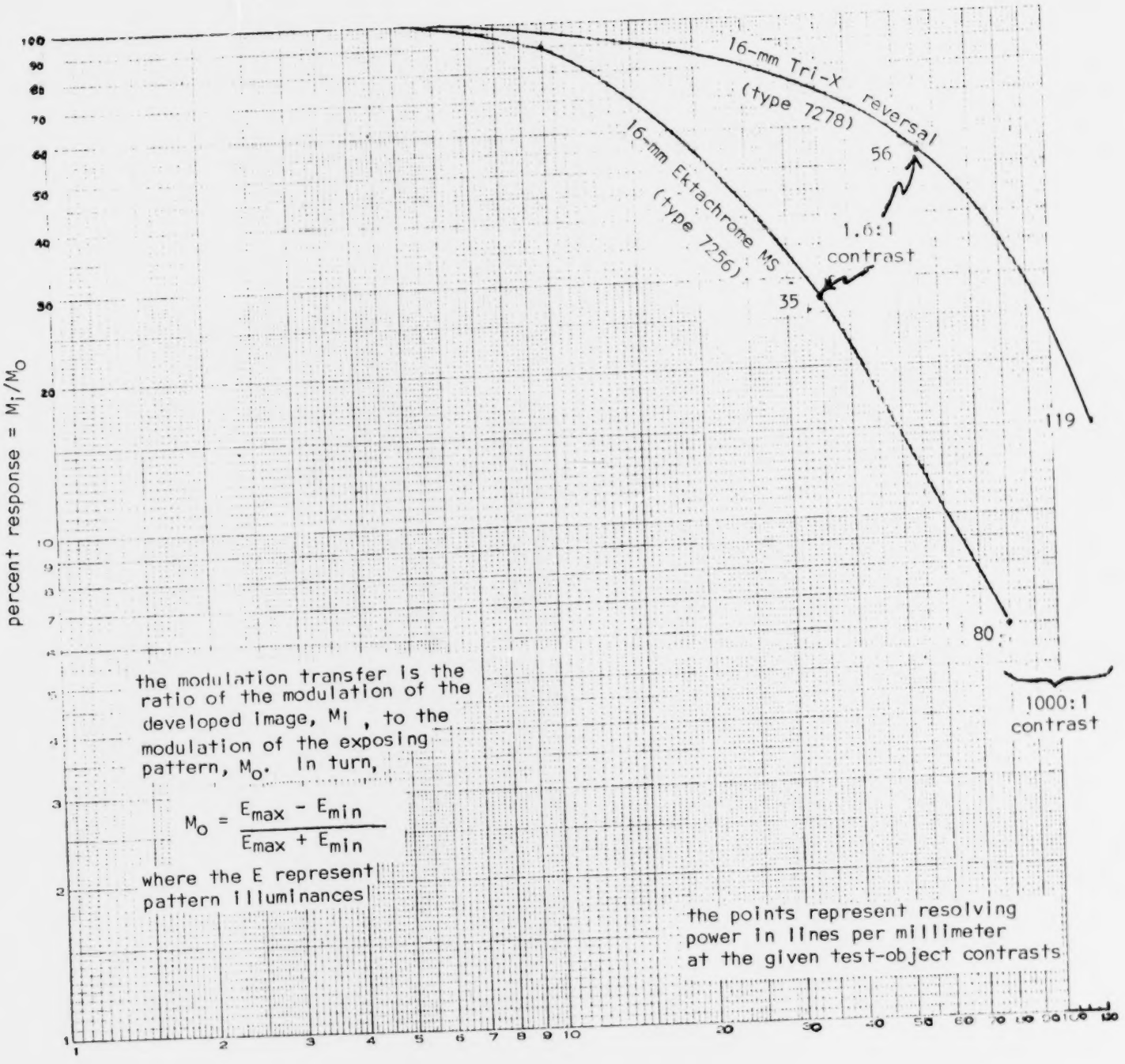

16-mm Tri-X reversal
(type 7278)
16-mm Ektachrome MS
(type 7256)
56
35
119
80
1.6:1
contrast
1000:1
contrast
percent response = $M_i/M_o$
the modulation transfer is the ratio of the modulation of the developed image, $M_i$, to the modulation of the exposing pattern, $M_o$. In turn,
$M_o = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$
where the E represent pattern illuminances
the points represent resolving power in lines per millimeter at the given test-object contrasts
spatial frequency, cycles per mm.

Figure 24: Modulation Transfer Functions for Black-and-White and Color Films (after references 277-279)

Black-and-white slides made for television may have the same photographic characteristic as those made for regular projection, except that contrast should be kept lower than is common in photographic practice. Negatives of scenes with a great brightness range (in excess of 20:1) should receive less than normal developing, if slides made from them are to televise well. Color transparencies should have a much more restricted contrast, not exceeding 2:1 or 3:1. Inherently, television seems to be contrast-enhancing. In televising opaques via the Telop device, it is found that a photograph which appears dull to the eye often shows up surprisingly well on television, but a snappy one may lose most of its tonal gradation (275).

## APPENDIX 8.2 DEMAND-ACCESS REQUIREMENTS FOR STILL-PICTURE TV PROGRAMS

Following an argument originally made by Hurtado (280), an analysis may be made of potential requirements for satellite-distributed educational television programs for use in U. S. elementary and secondary schools on a 100% demand-access basis.

Assume 2 million teachers, 10% of whom make a request for some program in any school day. In the first approximation, no allowance will be made for the same teacher making a request for several programs, nor for many teachers requesting the same program. Also, assume that each program runs an average of half an hour. Thus, if all requests were handled without some form of compression, the transmission requirement for full-motion television programs would be:

$$2 \times 10^6 \times 0.1 \times 0.5 = 10^5 \text{ program hours/day}$$

However, if all participating ground stations have storage capability, then programs can be transmitted 24 hours a day. This means that each hour $10^5/24 = 4170$ hours of programming can be sent.

Stated another way, 4170 full television channels must be provided to U. S. schools on a continuous basis if 100% demand access is required. This is an extreme case, which may be contrasted with the requirements of a 100% scheduled-access system. For example, 6 television channels provided for school use on a scheduled basis could carry 6 x 2 = 12 program hours per hour, or 288 program hours per 24-hour day. The difference between all-demand and all-scheduled access is 4170/12, or 348 times.

If it is assumed that 100 times savings can be realized in satellite bandwidth requirements using still-picture television instead of full-motion television programs, the transmission

requirements would be reduced to $10^5/10^2 = 10^3$ program hours per day or $10^3/24 = 41.7$ program hours every hour. In other words, the equivalent of 42 full TV channels would have to be provided to schools on a continuous basis. This is still an absurd requirement.

Up to this point in the analysis, no account has been taken of the number of television or still-picture programs which could be made available in actuality. However, reasonably good estimates of the number of educational media programs in existence can be obtained from NICEM's indexes:

| | |
|---|---|
| 16-mm motion pictures (281): | 27,500 |
| 35-mm filmstrips ( 77): | 21,500 |

(Most films are in sound, but possibly no more than 15% of the filmstrips have sound capability.)

For the still-picture television case, assume that a library of $2 \times 10^4$ different sound-filmstrip type programs could be made available, and that the $2 \times 10^6$ teachers make $2 \times 10^5$ requests/day, as in the original analysis. Then the overlap--i.e., the number of multiple requests for the same program on the same day--must average about $2 \times 10^5 \ / \ 2 \times 10^4 = 10$. Thus, the possible demand for TVE channels would be reduced by 10 times to 4 or 5 channels on a continuous basis--which is within reason. This argument holds no matter how great the number of program requests becomes; that is, the overlap of requests increases with the demand, because the number of different programs available remains constant.

Furthermore, circumstances likely to be encountered in practice should be considerably less demanding than the foregoing analysis would indicate. A common statistical phenomenon is the "80-20 law",

or more technically, "Zipf's law". The original "law", according to Zipf, stated that if all distinct items (types) in a population are ranked according to how often each is used (tokens), then $f_i = -\frac{K}{r_i}$, where $f_i$ is the frequency of use of type i, $r_i$ its rank, and k a constant, often equal to 10 (282).

While this phenomenon hardly deserves the appellation "law," it is a widespread observance in fields as different as linguistics and retail trade that only 20% of the types available account for 80% of the tokens used. Applying "80-20" to demand-access for still-picture programs, just two TVE channels should be adequate most of the time.

Furthermore, if the pattern of use for an educational communications satellite suggested in the EDUSAT study (see Table 2) is followed, four full TV channels would be made available. It is unlikely that there will be enough full television programs available to fill this capacity in the near future. If half of them were made available, a 100% demand-access service for still-picture programs would become feasible. It must be emphasized that no on-demand case can be made for transmitting 16-mm motion pictures via satellite, because they would take up a full television channel on a one-to-one basis.

## 9. BIBLIOGRAPHY


1. Washington University, "Progress Report. Program on Application of Communication Satellites to Educational Development", Submitted to Office of University Affairs, National Aeronautics and Space Administration, Washington, D. C., (98 pp.), November 12, 1970.

2. Hesselbacher, R. W., "Television Broadcast Satellite (TVBS) Study; TVBS Summary Report", Vol. 1, General Electric Company Space Systems Organization, Contract NAS 3-9708, NASA CR-72578, August 1, 1969.

3. Jansen, J., Jordan, P. L., et al., "Television Broadcast Satellite Study", TRW Systems Group, Contract NAS 3-9707, NASA CR-72510, TRW No. 08848-6002-R0-00, May 12, 1970.

4. General Dynamics. Convair Division, "Television Broadcast Satellite Study; Midterm Presentation", Convair Division of General Dynamics, Contract NAS 8-21036, July 7, 1969.

5. Schramm, Wilbur and Platt, William J., "Satellite-Distributed Educational Television for Developing Countries--Summary Report", Vol I., Stanford Research Institute, SRI Project 7150, Contract AID/csd-1901, (45 pp.), August 1968.

6. Stanford University. School of Engineering, "ASCEND: Advanced System for Communications and Education in National Development. An Interdisciplinary Engineering Course in Space Systems Engineering at Stanford University. Winter and Spring Quarters 1967. Final Report", Stanford University, (397 pp.), June 1967.

7. West Virginia University. College of Engineering, "STRIDE: Satellite Television Relay for India's Development and Education. An Interdisciplinary Course in Engineering Systems Design, Second Semester 1967. Final Report", West Virginia University, (338 pp.), May 1967.

8. Peters, M. P., editor, "EDUSAT, a Preliminary Design for an Educational Television Satellite System for the United States in the Mid-1970's", ASEE-NASA Langley Research Center--Old Dominion College Research Foundation, Summer Faculty Fellowship Program in Engineering Systems Design, (84 pp.), 1968.

9. Prasada, B., and Singh, J. P., editors, ACME: Advanced System for Communication and Mass Education for India's Development. An Interdisciplinary Course in Systems Engineering, January-May 1968. Final Report", Indian Institute of Technology, Kanpur, Television Centre, Department of Electrical Engineering, and Department of Mechanical Engineering, (232 pp.), June 1969.

10. Bretz, Rudy, "Communication Media: Properties and Uses", RAND Corporation, RM-6070-NLM/PR, (113 pp.), September 1969.

11. Simon, Kenneth A., and Grant, W. Vance, "Digest of Educational Statistics", 1970 edition, U.S. Department of Health, Education and Welfare, Office of Education, National Center for Educational Statistics, OE-10024-70, (140 pp.), September 1970.

12. Malcolm, Andrew H., "Shift of Tax Burden Sought", New York Times, (C 67), January 11, 1971.

13. Parsley, Kenneth, "Educational Solutions to School Financial Problems", Speech presented at Conference on Expenditure of the Educational Dollar, Washington University, November 13, 1970.

14. Elam, S., "The Age of Accountability Dawns in Texarkana", Phi Delta Kappan, (509-514), June 1970.

15. Jencks, C., "Giving Parents Money For Schooling: Education Vouchers", Phi Delta Kappan, (49-52), September 1970.

16. Illich, Ivan, "Education Without School: How It Can Be Done", (A Special Supplement), The New York Review, (25-31), January 7, 1971.

17. Committee for Economic Development, "Innovation in Education: New Directions for the American School", CED, July 1968.

18. Hope, T. W., "Market Review: Nontheatrical Film and Audio-Visual--1968", Journal of the SMPTE, Vol. 78, (973-988), November 1969.

19. U.S. Office of Education, "Educational Research and Development In The United States", OE-12049, (200 pp.), December 1969.

20. Silberman, Charles E., "Technology is Knocking at the Schoolhouse Door", Fortune, (120-125, 198, 203-205), August 1966.

21. Levitt, Theodore, "The New Markets--Think Before You Leap", Harvard Business Review, (53-67), May-June 1969.

22. Carlson, Elliot, "Education and Industry: Troubled Partnership", Saturday Review, (45-47, 58-59), August 15, 1970.

23. Locke, Robert W., "Has the Education Industry Lost Its Nerve?", Saturday Review, (42-44, 57), January 16, 1971.

24. Commission on Instructional Technology, "To Improve Learning; A Report to the President and the Congress of the United States", Committee on Education and Labor, House of Representatives, U.S. Government Printing Office, 1970.

25. Hooper, Richard, "A Diagnosis of Failure", AV Communication Review, Vol. 17, No. 3, (245-64), Fall 1969.

26. Dale, Edgar, "Audiovisual Methods in Teaching", Dryden Press, Holt, Rinehart and Winston, Inc., (719 pp.), 1969.

27. Edling, Jack, "Media Technology and Learning Processes", in Loughary, J. W., "Man-Machine Systems in Education", Harper & Row, (31-44), 1966.

28. Flory, John and Allen, William H., "Designing New Apparatus For Learning; A Survey of Needs For, and Developments In, Audiovisual Devices Suitable for Educational Uses", (USOE-SMPTE Conference on Audio-Visual Apparatus), Society of Motion Picture and Television Engineers, 1963.

29. Flory, John, "Audio-Visual Devices: Capabilities and Needs", Journal of the SMPTE, Vol. 72, No. 12, (938-942), December 1963.

30. Porter, Douglas, "A Critical Review of a Portion of the Literature on Teaching Devices", (114-132), in Lumsdaine, A. A., and Glaser, Robert, "Teaching Machines and Programmed Learning; A Source Book", National Education Association, Department of Audiovisual Instruction, (724 pp.), 1960.

31. National Educational Association. Association for Supervision and Curriculum Development, "A Report of an ASCD Seminar on a Theory of Instructional Materials", NEA-ASCD, 1960.

32. Saettler, Paul, "A History of Instructional Technology", McGraw-Hill Book Company, (399 pp.), 1968.

33. "Webster's Third New International Dictionary", G. & C. Merriam Company, 1961.

34. Tweney, C. F., and Hughes, L. E. C., editors, "Chamber's Technical Dictionary", 3rd edition, Macmillan, (1028 pp.), 1958.

35. Cooke, Nelson M., and Markus, John, "Electronics and Nucleonics Dictionary", 3rd edition, McGraw-Hill, (743 pp.), 1966.

36. "Midwest Program on Airborne Television Instruction--A Regional Exploration in Education", MPATI, Inc., (21 pp.), n.d.

37. Fall, W. R., "State Plan for Production and Distribution of Television Materials", MPATI, Inc., (8 pp.), July 18, 1968.

38. Ivey, Jr., John E., Perry, John L., and Bohnhorst, Ben A., "MPATI: Airborne Instructional Television in the United States", in "New Educational Media in Action: Case Studies for Planners--III", Unesco: International Institute for Educational Planning, (198 pp.), 1967.

39. Jameson, Kay Charles, "Airborne Television: MPATI and the FCC", Master's Thesis, Indiana University.

40. Fall, W. R., Personal Communication, January 1971.

41. Bronson, Vernon, et al., "Report of the NAEB Study on the Proposed Expansion of the Midwest Program on Airborne Television Instruction", National Association of Educational Broadcasters, (71 pp.), March 1964. (ERIC Document No. ED 003121)

42. Bronson, Vernon, et al.,"NAEB Technical Report on the Impact of Airborne Television Transmission on Land-Based UHF Television Assignment Plans", National Association of Educational Broadcasters, (44 pp.), April 1964. (ERIC Document No. ED 003113)

43. Steiner, Peter O., and Barnett, Harold J., "Comments of Economic Consultants", Exhibit No. 1 in "Comments submitted by the Midwest Program on Airborne Television Instruction Before the Federal Communications Commission, Washington, D. C.; In the Matter of Amendment of Part 3 of the Commission's Rules Governing TV Broadcast Stations to Authorize the Use of Airborne Television Transmitters, Docket No. 15201; In the Matter of Fostering Expanded Use of UHF Television Channels, Docket No. 14229", April 3, 1964.

44. "Instructional Television Fixed Service", EPIE Report, Vol. IV., No. 4, EPIE Institute, Kingston, New Jersey, (63 pp.), January 1971.

45. Glazier, Robert, Personal Communication, October 24, 1969.

46. Carnegie Commission on Educational Television, "Public Television; A Program for Action", Bantam Books, (254 pp.), 1967.

47. St. Louis Educational Television Commission, "1967-68 Annual Report", (20 pp.), 1968.

48. St. Louis Educational Television Commission, "Annual Report, 1968-1969", (16 pp.), 1969.

49. Belitsky, A. H., "Private Vocational Schools and Their Students: Limited Objectives, Unlimited Opportunities", Schenkman Publishing Company, (186 pp.), 1969.

50. Alexander, Sidney S., "Costs of a Nationwide Educational Television System", in Carnegie Commission on Educational Television, "Public Television: A Program for Action", (135-191), 1967.

51. Sheppard, E. M., "An Instructional Communications Satellite System For the United States", American Institute of Aeronautics and Astronautics Conference, Paper AIAA 70-450, April 6-8, 1970.

52. The Institute for Creative Studies, "Use of Satellite Technology In Education In the Continental United States", (73 pp.), October 1969.

53. Helmer, O., "The Use of the Delphi Technique in Problems of Educational Innovations", Rand Corporation, P-3499, (22 pp.), December 1966.

54. Dalkey, N. C., "The Delphi Method: An Experimental Study of Group Opinion", Rand Corporation, RM-5888-PR, (88 pp.), June 1969.

55. Bernstein, George B., "A Fifteen-Year Forecast of Information-Processing Technology", Naval Supply Systems Command, Research and Development Division, (181 pp.), January 20, 1969.

56. Dishler, J. J., "Visual Sensor Systems in Space", IEEE International Convention Record, Part I, Session 48, (105-116), 1967.

57. Salomon, P. M., "Applications of Slow-Scan Television Systems To Planetary Exploration", Journal of the SMPTE, Vol. 79, (607-615), July 1970.

58. Sullivan, M. V., "Apollo Black-and-White Television Scan Converter", Journal of the SMPTE, Vol. 79, (621-625), July 1970.

59. Hall, Geoffrey, "The Still Picture in Educational Television", Educational Television International, Vol. 3, No. 1, (55-57), March 1968; Vol. 3, No. 2, (164-169), June 1968; Vol. 3, No. 3, (270-274), September 1968.

60. Jamison, D., Jamison, M., and Hewlett, S., "Satellite Radio: Better Than ETV", Astronautics & Aeronautics, (92-96), October 1969.

61. Skornia, Harry J., "Educational Radio: Its Past and Its Future", in "Educational Television: The Next 10 Years", Stanford University, The Institute for Communication Research,(354-75), 1962.

62. Meyer, Richard J., "Charles A. Siepmann and Educational Broadcasting", AV Communications Review, Vol. 12, No. 4, Winter 1964.

63. Holmes, Brian and Gilliéron, C., "International Cooperation in School Radio and Television", in Bereday, George Z. F., and Lauwerys, Joseph A., editors, "The Year Book of Education, 1960: Communication Media and the School", Evans Brothers Ltd., (572-577), 1960.

64. Ozaeta, Pablo M., "The Radiophonic Schools of Sutatenza, Columbia", in Bereday, George Z. F., and Lauwerys, Joseph A., editors, "The Year Book of Education, 1960: Communication Media and the School", Evans Brothers Ltd., (557-564), 1960.

65. Travers, Robert M. W., "The Transmission of Information to Human Receivers", AV Communication Review, Vol. 12, No. 4, (373-385), Winter 1964.

66. Gregory, D. S., "Compressed Speech--The State of the Art", IEEE Transactions on Engineering Writing and Speech, Vol. EWS-12, No. 1, (12-17), May 1969.

67. Seo, H., "Electronic Speech Comprehension", Journal of the Audio Engineering Society, (320, 322, 324), June 1969.

68. Foulke, Emerson, "Methods of Controlling the Word Rate of Recorded Speech", Journal of Communication, Vol. 20, (305-314), September 1970.

69. McCormick, Ernest J., "Human Factors Engineering", 3rd edition, McGraw-Hill Book Company, (97), 1970.

70. Francisco, L. Mercer, "The More You Show The More You Sell; A Management Guide for Selecting, Creating and Using Profit Producing Selling Aids", Prentice-Hall, (287 pp.), 1960.

71. VanderMeer, A. W., "Forward", in National Center for Educational Media, Index to 35mm Educational Filmstrips, McGraw-Hill Book Company, (v-vi), 1968.

72. "Handbook for Production of Filmstrips and Records", 2nd edition, DuKane Corporation, St. Charles, Ill., 1965.

73. Dorsett, Loyd G., Dorsett Educational Systems, Inc., Norman, Oklahoma, Personal Communication, November 1970.

74. Andereck, Paul, Personal Communication, July 1970.

75. General Learning Corporation, "Cost Study of Educational Media Systems and Their Equipment Components", Vol. II, Technical Report, (334 pp.), June 1968. (ERIC Document No. ED 024286)

76. Twyford, Loran C., New York State Education Department, 1969 (cited in reference 24, page 66).

77. National Information Center for Educational Media, "Index to 35-mm Educational Filmstrips", 2nd edition, R. R. Bowker Company, (872 pp.), 1970.

78. A. N. A. Films Steering Committee, "The Dollars and Sense of Business Films", Association of National Advertisers, Inc., (64), 1954.

79. Large, Arlen J., "Spectrum Scramble: Air Wave Jam Worsens as More Radio Users Demand Frequencies", Wall Street Journal, (1 ff), December 5, 1969.

80. Miller, William C., "Film Movement and Affective Response and the Effect on Learning and Attitude Formation", AV Communication Review, Vol. 17, No. 2, (172-181), Summer 1969.

81. May, M. A., and Lumsdaine, A. A., editors, "Learning From Films", Yale University Press, (357 pp.), 1958.

82. Houser, R. L., Houser, E. J., and Van Mondfrans, A. P., "Learning A Motion and A Nonmotion Concept by Motion Picture Versus Slide Presentation", AV Communication Review, Vol. 18, No. 4, (425-430), Winter 1970.

83. "Broadcasting and Recording", Chapter 28 in"Reference Data for Radio Engineers", Howard W. Sams/ITT, 1968.

84. Boice, Clarence, "New Video Disc Slows and Stops the Action", Broadcast Management/Engineering, (48-49), June 1968.

85. Stratton, Lee "Reviewing Slow-Motion Disc Principles", Broadcast Engineering, (14-18), February 1969.

86. "Newell Model 1310 Video/Disc Recorder"; "Videonetics Model 1300 Stop-Action Recorder", (Product Brochures), Newell Industries, Videonetic Division, Sunnyvale, California, 1970.

87. Southworth, Glen R., "A Magnetic Disc Video-Scan Converter", Journal of the Society of Motion Picture and Television Engineers, Vol. 77, No. 6, (642-626), June 1968.

88. "Apollo Information Retrieval System", AV Electronics, Inc., Fresno, California, (34 pp.) 1970.

89. Matthews, M. V., et al., "The Technology of Computer Music", MIT Press, (188 pp.), 1969.

90. "The 15-MHz Instrumentation Recorder", (Product Brochure), Newell Industries, Inc., Sunnyvale, California, February 1969.

91. Sharma, G. M., "Still-Picture Tele sion Transmission", M.S. Thesis, Washington University, De tment of Electrical Engineering, 1971.

92. Zettl, H., "Television Production Handbook", 2nd edition, Wadsworth Publishing Company, (541 pp.), 1968.

93. Campbell, D. R., "MESA: A Time Division Multiple Access System", Globecom VI Digest of Papers, (61), 1964.

94. Koltay, E., "Standard Book Numbering", (47-49), in Wecksler, Sally, editor, "Publishers' World 69-70; A Yearbook For Publishers, Booksellers, Librarians", R. R. Bowker Company, (352 pp.), 1969.

95. Skinner, B. F., "Technology of Teaching", Appleton-Century-Crofts, (271 pp.), 1968.

96. Crowder, Norman A., "Automatic Tutoring by Intrinsic Programming", in Lumsdaine, A. A. and Glaser, Robert, editors, "Teaching Machines and Programmed Learning", National Education Association, (286-298), 1960.

97. Iverson, Kenneth E., "A Programming Language", John Wiley & Sons, 1962.

98. Iverson, Kenneth E., "The Role of Computers in Teaching", Queen's University, Papers in Pure and Applied Mathematics, No. 13, (53 pp.), 1968.

99. Alpert, D., and Bitzer, D. L., "Advances in Computer-Based Education", Science, Vol. 167, (1582-90), March 20, 1970.

100. Seidel, R. J., Kopstein, F. F., and Swallow, R. J., "CAI: Technological Misconceptions", (Letter to the Editor with Rebuttal by Alpert and Bitzer), Science, Vol. 168, (1397-1398, 1400), June 19, 1970.

101. Kopstein, F. F., and Seidel, R. J., "Computer-Administered Instruction Versus Traditionally Administered Instruction: Economics", Presentation at the National Society for Programmed Instruction, Boston, April 1967, HumRRO Professional Paper 31-67, June 1967.

102. Kopstein, Felix F., and Seidel, Robert J., "Computer-Administered Instruction Versus Traditionally Administered Instruction: Economics", AV Communication Review, Vol. 16, No. 2, (147-175), Summer 1968.

103. Carter, C. N., and Walker, M. J., "Costs of Installing and Operating Instructional Television and Computer-Assisted Instruction in Public Schools", Booz, Allen & Hamilton, Inc., 1968.

104. Nuthmann, C. F., "On the Feasibility of a 10,000 Terminal Time Shared Interactive Computer Controlled Educational Television (TICCET) System", MITRE Corporation, MTR-317, Rev. 1, (32 pp.), May 1969.

105. Stettin, K. J., Morton, R. P., and Mayer, R. P., "The Design and Testing of a Cost Effective Computer System for CAI/CMI Application", MITRE Corporation, (75 pp.), January 1970.

106. Nelson, F. B., "Twenty-Three Cent CAI System Aimed by Mitre", Datamation, (60-61), August 1, 1970.

107. "The Culler-Harrison Company Introduces Vox Putare: The Programmable Voice",(Product Brochure), The Culler-Harrison Company, Santa Barbara, California, 1969.

108. Meyer, Thomas C., " Establishing a Telephone Dial Access Medical Tape Recording Library: A Report", University of Wisconsin Medical Center, (13 pp.), 1967. (ERIC Document No. ED 021160)

109. University of Wisconsin Medical Center & University Extension, "Telephone Dial Access; Medical Tape Recording Library--List of Recordings", (n.d.).

110. Sargeant, C. W., "Audio Information Transfer", Proceedings, American Society for Information Science, Vol. 7, 33rd Annual Meeting, Philadelphia, (159-161), October 11-15, 1970.

111. Brick, Donald B., and Chase, Edward N., "Technology Profile: Interactive CRT Display Terminals. Part 1--The Technology and the Market", Modern Data, Vol. 3, No. 5, (62-69), May 1970.

112. Brick, Donald B., and Chase, Edward N., "Technology Profile: Interactive CRT Display Terminals. Part 2--Alphanumeric CRT Terminals", Modern Data, Vol. 3, No. 6, (70-85), June 1970.

113. Brick, Donald B., and Chase, Edward N., "Technology Profile: Interactive CRT Display Terminals. Part 3--Graphic CRT Terminals", Modern Data, Vol. 3, No. 7, (60-68), July 1970.

114. "Semiconductor Memories and Optoelectronics", (Special Issue), IEEE Journal of Solid-State Circuits, Vol. SC-5, No. 5, (235-283), October 1970.

115. "Flat-Screen Television Takes Two Giant Steps Forward", Electronics, (112-117), May 25, 1970.

116. Soxman, Ed, "Designing With LEF's--A New Display Technology", Electro-Optical Systems Design, Vol. 2, No. 9, (16-25), September 1970.

117. "Ferpics Perfect for Image Storage", Electro-Optical Systems Design, Vol. 2, No. 9, (7-8), September 1970.

118. Bitzer, D. L., and Slottow, H. G., "Principles and Applications of the Plasma Display Panel", Proceedings, Symposium on Microelectronics and Electronic Systems, IEEE Professional Group on Parts, Materials, and Packaging, §C6, (1 - 10), June 1968.

119. Baltzer, Donald H., "Nematic Crystals Come of Age", Electro-Optical Systems Design, (72-77), January 1970.

120. "New Approach to Alphanumeric Readouts; Inexpensive TV monitors Provide the Key to Low-Cost Display of Messages", The Electronic Engineer, September 1969.

121. Sutherland, I. E., "Computer Displays", Scientific American, (57-81), June 1970.

122. "Interactive Graphics for the Tektronix T4002 Graphic Computer Terminal", (Product Brochure), Tektronix, Inc., Beaverton, Oregon, 1970.

123. "Bendix ICD-1100, Graphic Interactive Computer Display Peripheral To the IBM-1130 Computing System; Introductory System Manual", Bendix Communications Division, Baltimore, Maryland, 1970.

124. "SD Datacolor", (Product Brochures), Spatial Data Systems, Inc., Goleta, California, 1970.

125. Bairstow, Jeffrey N., "And Now, This Important Message From Our Computer...", Computer Decisions, Vol. 1, No. 2, (50-53), November 1969.

126. "Electronic Visuals", Audio-Visual Communications, Vol. 4, No. 4, (14-15, 24-25), August 1970.

127. Post Office Department, "1969 Annual Report of the Postmaster General", U.S. Post Office Department, (257 pp.), 1970.

128. Federal Communications Commission, "Statistics of Communications Common Carriers, Year Ended December 31, 1968", Federal Communications Commission, (209 pp.), 1970.

129. President's Commission on Postal Organization (Kappel Commission), "Towards Postal Excellence", U.S. Government Printing Office, (212 pp.), June 1968.

130. Committee on Post Office and Civil Service, "Postal Rates and Revenue and Cost Analysis", U.S. House of Representatives, (377 pp.), 1970.

131. Codding, Jr., George A., "The Postal Service: A Tentative Obituary", Nation, (307), October 5, 1970.

132. Gross, W. B., "Distribution of Electronic Mail over the Broad-Band Partyline Communications Network", Proceedings of the IEEE, Vol. 58, No. 7, (1002-1013), July 1970.

133. Stein, Evelyn E., "Postal Reform Has Arrived", Book Production Industry, (40-41), September 1970.

134. Davidson, Leon, "A Push Button Telephone for Alphanumeric Input", Datamation, (27-30), April 1966.

135. Sinaiko, H. Wallace, "Preliminary Experiments in Teleconferencing", Proceedings of the Fifth National Symposium on Human Factors in Electronics, IEEE Professional Group on Human Factors in Electronics, (160-162), 1964.

136. Baber, Eric R., editor, "Report of a Pilot Program of Four Inservice Faculty Seminars Held in Four Illinois Junior Colleges by Means of a Telephone Conference Call", Illinois State University, (105 pp.), 1968. (ERIC Document No. ED 026995)

137. Pay, R. G., "Project Delphi--Technical Aid to Developing Countries By Consulting Services Satellite", AIAA 3rd Communications Systems Conference, Los Angeles, American Institute of Aeronautics and Astronautics, Paper No. 70-474, April 6-8, 1970.

138. Ohlman, Herbert, "How To Attend a Distant Conference at Home; The 1966 UNYSADI Teleconference", Proceedings, American Society For Information Science, Vol. 7, 33rd Annual Meeting, Philadelphia, (227-232), October 11-15, 1970.

139. Burkhart, James A., "An Experiment To Determine The Values Of Using Amplified Classroom Telephone Interviews With Significant Individuals to Enrich Certain College Courses; Final Report", Stephens College, (47 pp.), 1960. (ERIC Document No. ED 003514)

140. Jolly, Joan, and Madden, Charles F., "Amplified Telephone as a Teaching Medium", Stephens College, (95 pp.), March 1965. (ERIC Document No. ED 012620)

141. Jesser, David L., and Clarke, Michael J., "Art-By-Telephone", Nevada Western States Small Schools Project, (13 pp.), 1966. (ERIC Document No. ED 025359)

142. "Final Report on Two Inter-Institutional Programs Utilizing Amplified Telephone Communications", Stephens College, (26 pp.), September 1966. (ERIC Document No. ED 012621)

143. "Head Start Telelecture Project; A Feasibility Study to Assess The Potential of Telelecture as a Medium for In-Service Teacher Training in Appalachia", Education, Inc., Charleston, West Virginia, (39 pp.), August 1967. (ERIC Document No. ED 017163)

144. Rookey, E. J., "Graduate Instruction Via Telephone", Finger Lakes Region Supplementary Education Center, Homer, New York, (19 pp.), 1968. (ERIC Document No. ED 032767)

145. Kurland, J. R., "A Voice Broadcast Satellite System For Classroom Instruction", AIAA Paper 70-449, Presented at 3rd Communications Satellite Systems Conference, Los Angeles, California, April 1970.

146. Schultz, Donald G., and Schooley, Larry C., "An Economical Remote Teaching System", IEEE Transactions on Education, Vol. E-13, No. 3, (141-147), September 1970.

147. Cherry, Rona, "Something New on the Telephone", Parade, March 7, 1971.

148. "Picturephone", (Special Issue), Bell Laboratories Record, Vol. 47, No. 5, May/June 1965.

149. Skornia, Harry J., "Ratings and Mass Values", Chapter 6 in "Television and Society; An Inquest and Agenda for Improvement", McGraw-Hill Book Company, (120-142), 1965.

150. "Special Issue on Cable Television", Proceedings of the IEEE, Vol. 58, No. 7, July 1970.

151. Starlin, Glen, "Inter-Institutional Communications Networks", University of Minnesota, Paper prepared for the Feasibility Study of Inter-Institutional Television, (18 pp.), November 1966. (ERIC Document No. ED 024263)

152. Forsman, Marion E., "Graduate Engineering Education Via Television", International Convention of the IEEE, New York City, (18 pp.), March 18, 1968. (ERIC Document No. ED 019879)

153. Johnson, Eugene I., "Metroplex Assembly: an Experiment in Community Education", Center for the Study of Liberal Education for Adults at Boston University, (56 pp.), 1965.

154. Ohliger, John, "Listening Groups; Mass Media in Adult Education", Center for the Study of Liberal Education for Adults at Boston University, (78 pp.), 1967.

155. Meier, R. L., "A Communications Theory of Urban Growth", M.I.T. Press, (184 pp.), 1962.

156. Campbell, John O., and Gleason, Joseph P., "Design Parameters for Integrated Urban Communications", Journal of the SMPTE, Vol. 79, (532-535), June 1970.

157. Rees, David J., "State Film Utilization Survey--Plans for Improved Distribution and Use", in "Educational Communications 1963-1964, Proceedings of the New York State Convocation on Educational Communications", University of the State of New York, (139-147), 1964.

158. Andereck, P., Mitchell, D. R., and Beulick, J. C., "Missouri DAVE-DAVI Program: Proposed North Circle Project in St. Louis County, Missouri", in Griffith, B. L., and MacLennan, D. W., editors, "Improvement of Teaching by Television", University of Missouri Press, (139-155), 1964.

159. Andereck, Paul A., Mitchell, Don R., Boecklen, Warren A., and Bitzer, Ralph T., "North Circle Pilot Project; Phase A Report; The Feasibility of a Cooperatively-Owned Multi-Purpose, Multi-Channel, Closed-Circuit Television System for Instruction, Material Distribution, and Administrative Data Handling", Cooperating School Districts of the St. Louis Suburban Area, (138 pp.), October 1965.

160. Boecklen, Warren A., et al., "North Circle, Phase B Report; A Computer Study for the Allocation of Channels and The Placement of Transmitters for 2500 MHz Fixed-Station Service in a Metropolitan Area Containing Many Eligible Appplicants for Licensing", Cooperating Schools A-V Corporation of St. Louis County, June 1967.

161. Stewart, Donald K., editor, "Dial Access Information Retrieval Systems for Education, Newsletter", (irregular, 1964-1967), (first issued from University of Wisconsin's Articulated Instructional Media (AIM) Program; later from Texas A & M University's Center for the Creative Application of Technology to Education (CATE); lastly from Systems for Learning by Application of Technology to Education (SLATE).).

162. Mills, David L., "A Random-Access Multiple-Program System For the University of Michigan Language Laboratory", University of Michigan Department of Foreign Languages, (12 pp.), June 1969. (ERIC Document No. ED 031122).

163. Crossman, David M., "The Current State of the Remote Access Audio Video Information System", Audiovisual Education, (20-23), September 1970.

164. "Dial Access and Alternative Systems", EPIE Report, Vol. IV, No. 35, May 1971, EPIE Institute, Kingston, New Jersey.

165. Kuljian, Maynard J., "A Random-Access Audio-Picture Retrieval System", Journal of the SMPTE, Vol. 78, (869-872), October 1969.

166. Stewart, Donald K., "The Cost Analysis of Dial-Access Information Retrieval Systems for Education", University of Wisconsin Articulated Instructional Media Program (26 pp.), n.d.

167. Bidwell, C. M., and Auricchio, D., "A Prototype System for A Computer-Based Statewide Film Library Network: A Model For Operation; Final Report", Syracuse University Center for Instructional Communications, September 1968.

168. Morehouse, Harold G., "Telefacsimile Services Between Libraries With the Xerox Magnavox Telecopier, University of Nevada Library, December 20, 1966.

169. Schatz, Sharon, "Facsimile Transmission in Libraries--A State Of the Art Survey", Library of Congress Information Systems Office, (26 pp.), June 1967. (ERIC Document No. ED 016492)

170. Morehouse, H. G., "Equipment for Facsimile Transmission Between Libraries; a Description and Evaluation of Three Systems", University of Nevada Library and Council on Library Resources, Inc., (30 pp.), December 29, 1967. (ERIC Document No. ED 021566)

171. Schieber, William D., and Shottner, Ralph M., "Telefacsimile in Libraries: A Report of an Experiment in Facsimile Transmission and an Analysis of Implications for Interlibrary Loan Service", Institute of Library Research, University of California, (137 pp.), February 1968. (ERIC Document No. ED 019106)

172. Kenney, Brigitte L., "A Review of Interlibrary Communications Developments", in Henderson, Madeline M., compiler,"Proceedings of the Conference on Image Storage and Transmission Systems for Libraries Held on December 1-2, 1969", National Bureau of Standards, (316 pp.), September 1970.

173. Jones, C. R., "Facsimile", Murray Hill Books, 1949.

174. Shiers, G., "Early Schemes for Television", IEEE Spectrum, (24-34), May 1970.

175. Vermillion, C. H., "Weather Satellite Picture Receiving Stations Inexpensive Construction of Automatic Picture Transmission Ground Equipment: A Report", NASA Office of Technology Utilization, SP 5080, (83 pp.), 1969. (update of SP 5079)

176. "Facsimile Systems: A Survey", Book Production Industry, (42-45), December 1969.

177. Thompson, Brian J., "Application of Lasers to Printing and Recording", Image Technology, Vol. 11, No. 10, (16-24), August/September 1969.

178. RCA, "Experimental TV System That Can Broadcast Printed Copy Into The Home To Be Tested By RCA", (news release), RCA News, (3 pp.), June 12, 1967.

179. "Electronic Newsboy", (news item), Popular Science, (81), June 1970.

180. Facsimile Transmission Network, Inc., "FAXMAIL", (brochure), 1970.

181. Haley, Bader & Potts, "Petition for Rule Making; Before the Federal Communications Commission in the Matter of Amendment to Part 21, Sub part I, of the Rules and Regulations to Establish a Carrier Distribution Service (CDS), R.M. 1700", Microwave Communications, Inc., (34 pp.), October 9, 1970.

182. Glaser, M. L., "Application for Data Transmission Network System Description, Exhibit 1 (to FCC)", Datran (Data Transmission Company, a UCC Subsidiary), 1969.

183. Shaler, David, "An Ultra-High Speed Microfilm Facsimile System", AIEE Winter General Meeting, Conference Paper 62-249, (13 pp.), January 28-February 2, 1962.

184. Bond, D. S., and Duke, V. J., "Ultrafax", RCA Review, (99-115), March 1949.

185. Halsey, Richard S., "A Microform Cooperative for St. Louis Area Secondary Schools and Public Libraries (an ESEA Title III, P.K. 89-10, Planning Project), in Tate, Vernon D., editor, "Images in Action: Proceedings of the 17th Annual Meeting and Convention", NMA, (21-33), 1968.

186. Gardiner, A. W., "Typewriting and Office Duplicating Processes", Communication Arts Books, Hastings House Publishers, (168 pp.), 1968.

187. Wernikoff, Robert E., "Digital Facsimile", Signal, (19-22), December 1966.

188. Committee on Scientific and Technical Information, Federal Council for Science and Technology, "Federal Microfiche Standards", Office of Science and Technology, Executive Office of the President, First Edition, (PB 167630), (15 pp.), September 1965.

189. National Microfilm Association, "Proposed National Microfilm Association Microfiche Standard Specification", National Micro-News, No. 78, (60-69), October 1965.

190. Hays, D. G., et al., "A Billion Books for Education in America and the World: A Proposal", RAND Corporation Memorandum RM-5575-RC, (79 pp.), April 1968.

191. Cosden, Thomas B., "Microforms Look for a Place in Publishing", Book Production Industry, (42-46), January 1970.

192. Hawken, William R., et al., "Microbook Publication--a New Approach for a New Decade", Journal of Micrographics, Vol. 3, No. 4, (188-193), Summer 1970.

193. "The Microbook Library Series", (product brochure), Library Resources, Inc., (16 pp.), 1970.

194. "Britain's Largest Information Retrieval Service Launched", Microdoc, Vol. 8, No. 3, (64-69), 1969.

195. "Here Are The Books Behind the Bibliographies...", (catalog), NCR Educational Products Department, Dayton, Ohio, (123 pp.), 1970.

196. "1971 Edition; PCMI Library Collection. American Civilization", (catalog), NCR Educational Products Publishing Systems, Industrial Products Division, Dayton, Ohio.

197. Ver Hulst, Jack, "Microfilm Information Systems", Paper presented at Conference on Image Storage and Transmission For Libraries, National Bureau of Standards, December 1-2, 1969.

198. Crew, Wynn D., "The Microaperture: A Design to Substitute For A Book", Journal of Micrographics, Vol. 4, No. 1, (3-11), October-November 1970.

199. Eastman Kodak, (publicity release), Scientific Information Notes, Vol. 2, No. 1, (13), 1970.

200. Fernández-Morán, H., "Potential Application of Electron-Optical Methods to Storage of Information for Direct Retrieval", Appendix II to "Biology and the Exploration of Mars", NAS-NRC Publication No. 1296, 1966.

201. Whyte, Bert, "Electronic Video Recording", Audio, (8-12), February 1969.

202. Genesky, S. M., Moshin, H. L., and Steingold, H., "A Closed Circuit Television System for Visually Handicapped and Prospects for Future Research", RAND, P-4147, (20 pp.), July 1969.

203. Avedon, D. M., "Computer Output Microfilm", NMA Monograph #4, 1969.

204. Koeneman, John K., and Schwanbeck, John R., "Computer Microfilm--A Cost Cutting Solution to the EDP Output Bottleneck", AFIPS Conference Proceedings, Vol. 35, Fall Joint Computer Conference, Las Vegas, (629-635), November 18-20, 1969.

205. Gildenberg, Robert F., "Technology Profile: Computer Output Microfilm Systems", Modern Data, Vol. 3, No. 11, (78-82, 84-93), November 1970.

206. Workman, William E., "The Picturephone Puts Data at Management's Fingertips", Computer Decisions, (36-39), October 1970.

207. Industrial Electronics Division, Electronic Industries Association, "The IED/EIA Response to the Federal Communications Commission Docket 18397, Part V, The Future of Broadband Communications", IED/EIA, (44 pp.), October 29, 1969.

208. Barnett, Harold J., Statement of Harold J. Barnett, Economic Consultant, National Cable Television Association, Inc., before the Federal Communications Commission on Parts III and IV of the Notice of Proposed Rulemaking and Notice of Inquiry in Dockett 18397, (28 pp.), Feburary 3, 1969.

209. Barnett, H. J., and Greenberg, E., "A Proposal for Wired City Television", Washington University Law Quarterly, Vol. 1968, No. 1, (1-25), Winter 1968.

210. Barnett, Harold J., "Resistance to the Wired City", Washington University Department of Economics Research Monograph No. 12-70, (54 pp.), December 27, 1970.

211. Barnett, Harold J., and Greenberg, Edward, "Regulating CATV Systems: An Analysis of FCC Policy and an Alternative", Law and Contemporary Problems, Vol. 34, No. 3, (562-585), Summer 1969.

212. Jones, William K., "Regulation of Cable Television By the State of New York. Report to the Commission", State of New York, Public Service Commission, (220 + 79 pp.), December 1970.

213. Bishop, J. E., "Stretched Spectrum: New Radio Band Gives Promise of Relieving Communications Jam", Wall Street Journal, (1), November 24, 1970.

214. "Two-Way Communication in a CATV System, (Subscription Television, Inc.), BM/E, (28-30), June 1970.

215. Dowlin, Kenneth E., "CATV + NCPL = VRS; Broadcasting Reference Service Over a Community TV System", Library Journal, (2768-2770), September 1, 1970.

216. Aaronson, Charles S., "1968 International Television Almanac", Quigley Publications, (774 pp.), 1967.

217. Park, Rolla E., "Cable Television and UHF Broadcasting", Rand Corporation, R-689-MF, (46 pp.), January 1971.

218. McClannan, Q. B., and Heckert, G. P., "A Satellite System for CATV", Proceedings of the IEEE, Vol. 58, No. 7, (987-1001), July 1970.

219. McLean, F. C., "Telecommunications--The Next 10 Years", in"The Granada Guildhall Lectures: Communications in the Modern World", MacGibbon & Kee, Ltd.

220. Gilkey, R., "Cassettes: Their Promise and Temporary Limitations", Educational Product Report, Vol. 3, No. 5, (4-7), February 1970.

221. Hanson, Edward R., "A Tape Cassette Standard", Journal of the Audio Engineering Society, Vol. 16, No. 4, (430-435), October 1968.

222. Humphreys, Don, "The 8-Track/Cassette Cold War Gets Warmer", Audio, (50-51), January 1970.

223. Canby, Edward T., "Cassettes and the Dolby System", Audio, (40), May 1970.

224. Nevin, D., "Microfilm Cartridges (Cassettes? Containers?) in Libraries", Washington University Librarian, Vol. 2, No. 7, (4), April 15, 1970.

225. Movshon, George, "The Video Revolution", Saturday Review, (50-52), August 8, 1970.

226. Aaron, Chloe, and Kahlenberg, Richard, "The Cartridges Are Coming!", Media & Methods, (50-65), September 1970.

227. "The Video Playback Race", BM/E, Vol. 6, No. 11, (32-35), November 1970.

228. "TV Cassettes", (special cassette symposium), Variety, 65th Anniversary Edition, Vol. 261, No. 8, (1, 62-64, 66, 68, 80, 82), January 6, 1971.

229. Alpert, Hollis, "Cassette-TV: The Cassette Man Cometh", Saturday Review, (42-44, 60), January 30, 1971.

230. Berger, Ivan, "Cassette-TV: Someday Morning for the Culture Cans", Saturday Review, (45-47), January 30, 1971.

231. National Association of Educational Broadcasters, "Television Cartridge and Disc Systems: What Are They Good For?", National Association of Educational Broadcasters, Washington, D. C., (57 pp.), February 1971.

232. Schwalberg, Bob, "Photography's Electronic Future", Popular Photography", (64-69, 138, 142), March 1971.

233. Witherspoon, John P., and Kessler, William J., "Instructional Television Facilities: A Planning Guide", U. S. Department of Health, Education and Welfare, Office of Education, OE-34043, (73 pp.), 1969.

234. "See Your Home Movies on TV", Popular Science, (23), June 1970.

235. Sylvania, "Color Slide Theatre: Technical Description and Service Instructions", GTE-Sylvania, 05-24365-1, (26 pp.), n.d.

236. "8mm and the TV Cartridges", Deluxe General Rewind, Vol. 12, No. 6, (2-3), November/December 1970.

237. "Taking a Look at Color EVR From the Inside Out", Electronics, (94-101), April 27, 1970.

238. Goldmark, Peter C., "Color EVR", IEEE Spectrum, (22-33), September 1970.

239. Goldmark, P. C., et al., "Color Electronic Video Recording", Journal of the SMPTE, Vol. 79, No. 8, (677-686), August 1970.

240. Hannan, W. J., "Holographic Movies for TV Viewing", RCA Engineer, Vol. 16, No. 1, (14-18), June-July 1970.

241. Joe, Radcliffe, "RCA Shelves CTV Unit--Hunts Interim System", Billboard, (1, 26), March 6, 1971.

242. "$50-mil RCA Vidcassette Bet", Variety, Vol. 260, No. 11, (1), October 28, 1970.

243. Farr, Kenneth E., "Phonovid--A System for Recording Television Pictures On Phonograph Records", Journal of the Audio Engineering Society, Vol. 16, No. 2, (163-167), April 1968.

244. "World Premiere Video Disc, Berlin 1970", Allgemeine Elektricitäts-Gesellschaft AEG-Telefunken & Teldec Telefunken-Decca Schallplatten-Gesellschaft M.B.H., (44 pp.), June 24, 1970.

245. Redlich, Horst, "The Video Disc Technique--Recording and Reproduction (I- -Recording), in "World Premiere Video Disc, Berlin 1970", AEG-Telefunken & Teldec, (44 pp.), June 24, 1970.

246. "MCA Hatching Home Teledisk; 90 Mins. Play?", Variety, Vol. 260, No. 10, (1), October 21, 1970.

247. King, Ellis F., "Electronic Transmission for Interlibrary Loans", American Documentation, Vol. XI, (32-39), 1960.

248. Heilprin, L. B., "The Economics of 'On Demand' Library Copying", Proceedings, National Microfilm Association, (311-339), 1962.

249. Simonds, J. L., "Information Technology for Network Operations", in Tate, V. D., editor,"Proceedings of the Eighteenth Annual Meeting and Convention", National Microfilm Association, (51-58), 1969.

250. Veaner, Allen, Personal Communication, December 1969.

251. McMains, H. J., and Bromleigh, Jr., "Telephony and The Library", (19 pp.), in Henderson, Madeline M., compiler, "Proceedings of the Conference on Image Storage and Transmission Systems for Libraries Held on December 1-2, 1969", National Bureau of Standards, (316 pp.), September 1970. (PB 193692)

252. Shannon, C. E., "A Mathematical Theory of Communication", Bell System Technical Journal, Vol. 27, (379-433, 623-656), July, October 1948.

253. Hogan, John V. L., and Wilmotte, R. M., "Auditory Aids in the Classroom: A Report on the Cost of Providing Auditory Aids by Broadcasting, by Wire Lines and by Records", Committee on Scientific Aids to Learning, (66 pp.), August 1938.

254. Andereck, Paul, Personal Communication, May 1971.

255. Sovereign, M. G., "Comparative Costs of Instructional Television Distribution Systems", Ph.D. Thesis, Purdue University, (171 pp.), June 1965.

256. Sovereign, Michael G., "Costs of Educational Media Systems", (abridgement), ERIC at Stanford, Series II Paper, (28 pp.), June 1969.

257. Weise, Duane M., "Computerized Techniques for Complete Television Station Automation", IEEE Transactions on Broadcasting, Vol. BC-14, No. 4, (151-160), December 1968.

258. "Proceedings of the Invitation to Industry", United States Postal Service, (249 pp.), September 14-16, 1970.

259. Lavianna, Donald, Personal Communication, Westinghouse Learning Corporation, December 1969.

260. Bretz, Rudy, "The University of Texas Dental Branch Independent-Access Television System", RAND Corporation, P-4304, (18 pp.), February 1970.

261. Ball, Samuel, and Bogatz, Gerry Ann, "The First Year of Sesame Street: An Evaluation; a Report to the Children's Television Workshop", Educational Testing Service, (480 pp.), October 1970.

262. "SCA Spells More $$ for Fm", BM/E, (22-25, 48), February 1969.

263. Beard, Richard L., "Development and Utilization of the Frequency Modulation Subcarrier as a Commercial Communications Medium", Ph.D. Dissertation, University of Illinois Department of Communications, (164 pp.), 1965.

264. Parker, Lorne A., "The Development and Utilization of the Subsidiary Communications Authorization 1900-1967", M. S. Thesis, University of Wisconsin.

265. Porterfield, John, "Fax to Get the Facts There Fast", BM/E, (28-29), February 1969.

266. Kamen, Ira, "Education at Home via SCA", BM/E, (26-27), February 1969.

267. Oden, H., "Push-Button Selection: A Characteristic of Modern Switching Systems", Electrical Communication, Vol. 45, No. 1, (66-71), 1970.

268. Clarke, A. C., "Profiles of the Future; An Inquiry into the Limits of the Possible", Harper and Row, (234 pp.), 1962; Bantam Books, 1964.

269. Winthrop, H., "Ventures in Social Interpretation", Appleton-Century-Crofts, (551 pp.), 1968.

270. Reiser, Oliver L., "The Integration of Human Knowledge: A Study of the Foundations and Social Implications of Unified Science", Porter Sargent Publishers, 1958.

271. Le Corbusier (pseudonym for C. E. Jeanneret-Gris), "The Modulor, A Harmonius Measure to the Human Scale Universally Applicable to Architecture and Mechanics", 2nd Edition, Faber and Faber, (243 pp.), 1954.

272. Tinker, Miles, "Legibility of Print", Iowa State University Press, (329 pp.), 1963.

273. Bretz, Rudy, "Multi-Image Films at Expo '70: A Trip Report", RAND Corporation, P-4499, (54 pp.), November 1970.

274. Bogatov, G. B., "Television Transmission From Outer Space", (edited machine translation of "Televizionnyye Peredachi iz Kosmosa", Izdatel'stvo "Nanka", Moskva, 1966), Foreign Technology Division, Wright Patterson Air Force Base, Ohio, FTD-MT-24-229-67.

275. Carroll, John S., editor, "Photo-Lab-Index", 20th Edition, Morgan and Morgan, Inc., January 1961.

276. Ross, Rodger J., "Television Film Engineering", John Wiley & Sons, Inc., (507 pp.), 1966.

277. "Modulation Transfer Data for Kodak Films", Eastman Kodak Company, Instrumentation Products Sales, Kodak Pamphlet No. P-49, 3rd Edition, (15 pp.), September 1967.

278. "Kodak Tri-X Reversal Film 7278 (16 mm)", Eastman Kodak Company, Motion Picture and Education Markets Division, Kodak Publication No. H-1-7278, (4 pp.), July 1968.

279. "Kodak Ektachrome MS Film (Daylight), Types 5256 (35 mm) and 7256 (16 mm)", Eastman Kodak Company, Motion Picture and Education Markets Division, Kodak Publication No. H-1-5256, (4 pp.), n.d.

280. Hurtado, Marco, Personal Communication, 1970.

281. National Information Center for Educational Media, "Index to 16mm Educational Films", 2nd Edition, R. R. Bowker Company, (1111 pp.), 1969.

282. Zipf, George Kingsley, "Human Behavior and the Principle of Least Effort; an Introduction to Human Ecology", Addison-Wesley Press, (573 pp.), 1949.

## 10. VITA

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June, 1971